THE GENERATION OF OPTICALLY ACTIVE 1,3-DIARYLALLENES FROM SUBSTITUTED **CIS**-2,3-DIARYLCYCLOPROPYLIDENES

By
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Abstract of Dissertation Presented to the Graduate Council in Partial Fulfillment of the Requirements for the Degree of

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The purpose of this research was to synthesize and study a number of substituted cyclopropylidenes in which electronic factors would outweigh steric factors in the ring opening of the cyclopropylidene to allene. The synthesis and study of the substituted cyclopropylidenes was carried out in the following manner.

Several cis-2,3-diarylcyclopropanecarboxylic acids were prepared by the addition of ethyl diazoacetate to substituted cis-stilbenes, which were prepared by conventional methods. The acids were resolved and converted to the ethyl N-nitroso-N-(cis-2,3-diarylcyclopropyl)carbamates via the acid chloride, acid azide, isocyanate, and carbamate. Decomposition of the N-nitrosocarbamates with base gave optically active 1,3-diarylallenes.

The activity of the allenes was shown to arise only from the cis-2,3-diarylcyclopropanecarboxylic acids, by

preparation of the methyl ester and n-butyl ketone of each acid and GLC analysis. The methyl-trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylate and trans-2-p-methylphenyl-3-phenylcyclopropyl butyl ketone were synthesized for comparison with the corresponding cis compounds via GLC analysis.

A chemical correlation scheme relating the (-)-cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid to the (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid was carried out. The (-)-1-p-methylphenyl-3-phenylallene was also related to the (+)-1-p-bromophenyl-3-p-methylphenylallene by chemical reactions. From this chemical correlation scheme, relatively speaking, it was found that the (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid gave allene of highest optical purity. The optical purity and relative absolute configuration data obtained from the correlation scheme tend to support an electronically influenced ring opening of the cis-substituted cyclopropylidene to a 1,3-diarylallene. The arguments involved in a steric versus an electronic ring opening are discussed.

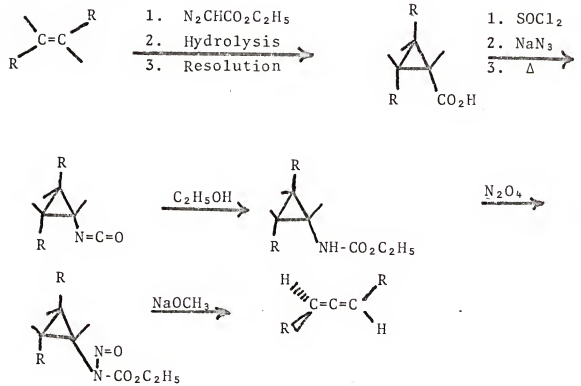
CHAPTER I

THE GENERATION OF OPTICALLY ACTIVE 1,3-DISUBSTITUTED ALLENES

Introduction

Recently, a general method for synthesizing optically active 1,3-disubstituted allene hydrocarbons was developed by Jones, et al. (1-3). The general synthetic scheme involved is shown below.

Scheme I



R = C_6H_5, $(CH_2)_3CH_3$, C_2H_5, or CH_3

The desired starting trans-2,3-disubstituted cyclopropanecarboxylic acid was prepared by reaction of ethyl diazoacetate with the appropriate olefin, followed by hydrolysis of the resulting ester. The acid was resolved and converted to the corresponding acid chloride by treatment with thionyl chloride. Conversion of the acid chloride to the acid azide by way of sodium azide in acetone-water and heating of the acid azide in refluxing benzene gave the corresponding isocyanate. Treatment of the isocyanate with absolute ethanol and dinitrogen tetroxide gave the ethyl N-nitroso-N-(trans-2,3-disubstituted cyclopropyl)carbamate. Treatment of the ethyl N-nitroso-N-(trans-2,3-disubstituted cyclopropyl)carbamate with sodium methylate gave the optically active 1,3-disubstituted allene hydrocarbons.

Several studies have shown that the substituted diazocyclopropane and cyclopropylidene are intermediates in the decomposition of substituted N-nitrosocarbamates and ureas with base to give allenes (1-2, 4-9). In devising the above synthetic scheme, it was hoped that the dissymmetry in the diazocyclopropane and cyclopropylidene intermediates would be retained in the formation of the allene. Recently, evidence has been presented to suggest that the cyclopropylidene may be the only precursor to the allene (10). In the ring opening process of a trans-substituted cyclopropylidene to the allene, the steric interactions of the two

trans substituents are believed to be the controlling factor involved leading to the high activity of allene formed (11-12).

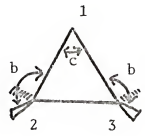
In contrast to a sterically controlled ring opening, as in the systems above, it was thought that the stereochemistry of the ring opening might also be affected by electronic factors. The purpose of this work was to explore this possibility.

Method

To better understand the method used to determine if the stereochemistry of the ring opening could be affected by electronic factors, the arguments surrounding the steric factors involved in the conversion of trans-2,3-diphenyl-cyclopropylidene to allene will be presented.

Basically, three things must happen when a substituted cyclopropane is opening to an allene. First, the C_2 - C_3 bond must break. Second, the angles b and c must increase to 180°. And third, the planes x and y must rotate 90° with respect to each other (1-2, 11).

One will note that if angles b and c become 180° before planes x and y rotate, then the resulting intermediate will have a plane of symmetry, and the resulting allene will be optically inactive. Therefore, to obtain asymmetry in the allene, the planes x and y must begin to rotate before angles b and c increase to 180°, and the opening process must be concerted.



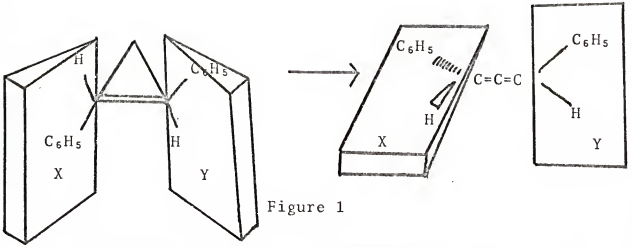
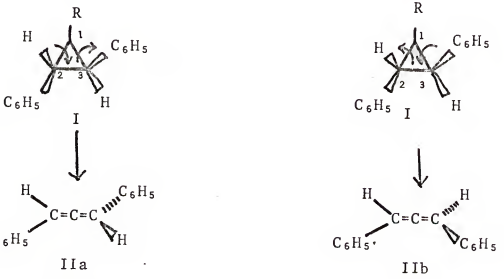


Figure 1

The steric interactions occurring in the ring opening can best be visualized if one considers the compounds shown below. The orthogonality of the double bonds in the allene



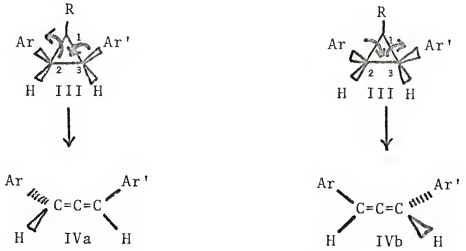
R = electron pair

Figure 2

require the opening rotation to be conrotatory; a disrotatory opening would lead to a planar product. As shown, each of the two conrotatory ring opening processes leads to a different enantiomer of the allene. It was found that the preferred direction of conrotatory opening cannot be predicted using symmetry arguments (13), but that simple steric arguments could be used (2, 11). In the opening of compound I, a clockwise rotation will bring the hydrogen atom on C_2 into interaction with the hydrogen atom on C_3. A counterclockwise rotation of I will bring the phenyl on C_2 into interaction with the phenyl on C_3. One would predict a preference for the clockwise opening to give enantiomer IIa over enantiomer IIb. In accord with this proposal is the finding that trans-2,3-diphenylcyclopropylidene of absolute configuration I (as determined by an unequivocal chemical correlation on the starting acid (11)) yielded predominantly (+)-1,3-diphenylallene of structure IIa (as determined by circular dichroism studies of Mason and Vane (12)).

Applying the same considerations to the cis-2,3-disubstituted cyclopropylidene III, and assuming no electronic effects are operating and the steric requirements of the two aryl groups are the same, the two distinguishable conrotatory ring opening processes, leading to different enantiomers of the allene, must occur with the same probability and the resulting allene must be inactive.

Again, in this case a disrotatory opening would lead to a planar product.



R = electron pair

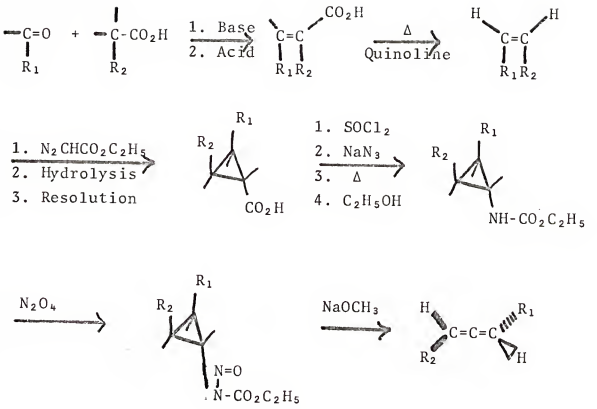
Figure 3

The method employed to study electronic effects was therefore to synthesize cis-2,3-disubstituted cyclopropylidenes in which the electronic difference in the two groups could be clearly shown to outweigh steric differences.

Results

To minimize the steric effect, para substituted cis-2,3-diarylcyclopropylidenes were synthesized according to the reaction scheme shown in scheme II.

Scheme II



R_1	R_2
a)-ϕ-CH_3	-ϕ-H
b)-ϕ-Cl	-ϕ-H
c)-ϕ-CH_3	-ϕ-Br

The cis-stilbenes were prepared by decarboxylation of the substituted α-phenyl-trans-cinnamic acids using copper chromite in quinoline (14). The substituted α-phenyl-trans-cinnamic acids were prepared by a modified procedure of Buckles and Bremer (15). One interesting aspect of the decarboxylation reaction was observed. If R_1 = ϕ-Br and R_2 =

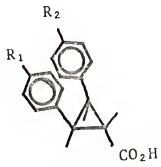
ϕ-CH_3, the substituted α-phenyl-trans-cinnamic acid will not decarboxylate. However, if R_1 = ϕ-CH_3 and R_2 = ϕ-Br, the substituted cinnamic acid readily decarboxylates to give the corresponding cis-stilbene.

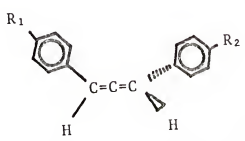
Since both cis and trans-stilbenes were produced in the decarboxylation reaction, the cis-stilbene was separated from the trans-stilbene before the olefin was treated with carbethoxy carbene. The method used for separation of the isomers involved cooling a hexane mixture of the stilbenes to 0^{o} and filtering off the trans compound (16), followed by column chromatography over neutral alumina (hexane eluent) (17-18). Final purification of the cis-stilbene was obtained by distillation. All substituted cis-stilbenes that were reacted with carbethoxy carbene were shown to be geometrically pure within the limits of GLC analysis.

Addition of carbethoxy carbene to the substituted cis olefins, followed by hydrolysis, gave the cis-2,3-diaryl-cyclopropanecarboxylic acids. The acids were resolved by recrystallization of their ephedrine salts. The optically active acids were then treated with the same reagents (with a modification in some of the procedures) as was the optically active trans-2,3-diphenylcyclopropanecarboxylic acid in its conversion to allene. These reactions were discussed under scheme I.

Optically active 1,3-disubstituted allenes were obtained from all three optically active cis-2,3-diaryl-cyclopropanecarboxylic acids that were employed in the reaction scheme II. The rotations of the acids and allenes are given below.

Scheme III





	R_1	R_2	Rotation of Acid	Rotation of Allene
a)	Cl	H	$(\alpha)^{22}_{436} = -5.73^{o}$	$(\alpha)^{22}_{436} = +5.95^{o}$
b)	CH_3	H	$(\alpha)^{22}_{436} = -1.00^{o}$	$(\alpha)^{22}_{365} = -36.10^{o}$
c)	CH_3	Br	$(\alpha)^{23}_{436} = -8.24^{o}$	$(\alpha)^{22}_{365} = +101.0^{o}$

The allenes were purified by chromatography on a silica gel column (hexane eluent). Fractions containing the allene were combined and made up to a standard volume. The rotations of the 1,3-disubstituted allenes given above are of the allene in hexane solution. This method was used to determine the optical activity of the allenes because it was found that if one placed the hexane solution containing the allene in a dry ice-acetone bath to crystallize the allene, the precipitate could be almost optically inactive, but the hexane solution of allene left would be optically

active. It seems then that mostly racemic allene will crystallize from a hexane solution, leaving the enantiomer that was in excess in solution, thus giving a higher activity allene solution and a low activity allene precipitate (19).

Since optically active trans-2,3-diphenylcyclopropanecarboxylic acid ($(\alpha)^{22}_{589} = -23.87^{o}$) gave 1,3-diphenylallene of quite high optical activity ($(\alpha)^{25}_{589} = +459^{o}$) (1), it was necessary to show that no trans-2,3-diarylcyclopropanecarboxylic acid was present in the corresponding cis acid. The method chosen for this study was to allow the cis acid to react with diazomethane to produce the corresponding methyl ester, and then use GLC to determine if any trans compound was present.

The trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid was synthesized, for comparison with the corresponding cis compound, according to the scheme outlined below. The reaction of p-tolualdehyde with the Grignard reagent of benzyl chloride gave, upon addition of water and acid, the trans-4-methylstilbene (20a). The trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid was obtained upon treatment of the trans-4-methylstilbene with ethyl diazoacetate and subsequent hydrolysis of the ester.

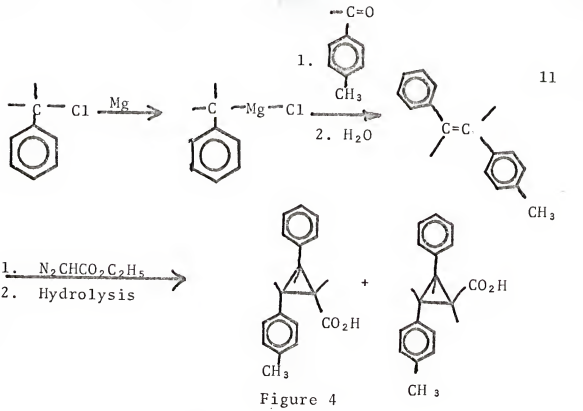


Figure 4

The n.m.r. spectrum of trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid was distinctly different from that of the corresponding cis compound. The n.m.r. spectrum of the trans compound gave a complex multiplet at τ 7.00 for the two cyclopropane hydrogens adjacent to the phenyls. The cis acid gave a doublet for these two hydrogens at τ 6.95 (J = 5 cps). The coupling constant is in agreement with the stereochemistry shown in scheme II for the cis acid, where the two aryl groups are cis to each other and each is trans to the acid function (20b). No trans compound could be detected in the cis compound by n.m.r. spectrum analysis.

In both the cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid and cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid, the n.m.r. spectrum showed only

a doublet for the two cyclopropane hydrogens adjacent to the phenyls, similar to the cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid described above.

When the esters of cis and trans methyl-2-p-methylphenyl-3-phenylcyclopropanecarboxylate were analyzed by GLC, no trans compound could be detected in the cis compound. From known samples of cis and trans esters analyzed via GLC, it was determined that the maximum amount of trans compound that could be present in the cis compound would be less than 0.10 percent. When the methyl esters of (-)-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid and (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid were analyzed by GLC, only one peak was observed for each compound. Further discussion and proof that only the cis isomers are present will be presented later.

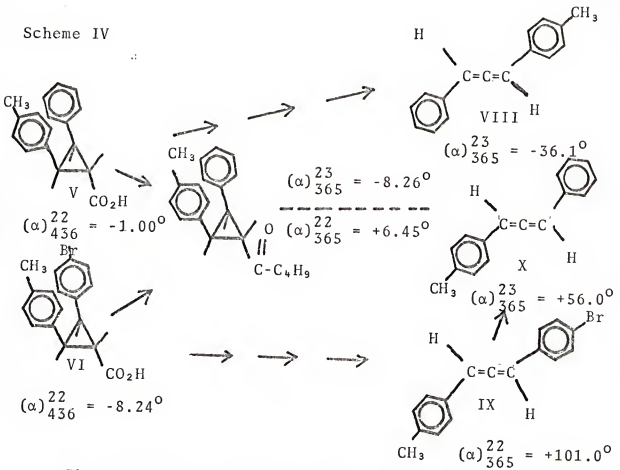
Since the trans-2,3-diphenylcyclopropylidene was trapped via treatment of the N-nitrosocarbamate with base in the presence of olefins, to give a spiro compound (10) (20% yield), it was hoped that the carbene intermediate could be trapped in like manner for the cis systems. However, when ethyl N-nitroso-N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate was treated with base in cyclohexene as a solvent, only allene product was isolated from the reaction mixture in the usual yield. No other product besides the allene could be detected by GLC analysis. The N-nitrosocarbamate was

also decomposed in isobutylene as a solvent. Again, only allene product was isolated and no spiro compound was detected. A discussion of this result will be taken up in the next chapter.

The results of this work showing that optically active allenes could be obtained from the appropriate cis-substituted cyclopropane compounds are indeed interesting, but one cannot say if electronic effects outweigh steric effects. In theory, this could be determined if the absolute configuration of both acid and allene, compounds a and b of scheme II , were known. The electron donating methyl in system a should promote ring opening in a direction opposite to that of the electron withdrawing chlorine of system b.

In view of the formidable nature of determining the absolute configurations, a more feasible solution to this problem was sought. The approach that was finally selected is presented in the following scheme. Scheme IV was devised with the thought in mind that substituted cyclopropanes and olefins have been shown to be configurationally stable to n-butyllithium and methyllithium (21-24).

Scheme IV



The conversion of both acids to the same ketone compound tells one the relative optical purities of the acids and also the relative absolute configurations of the acids. It was found that the (-)-cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid ($(\alpha)^{22}_{436} = -1.00^{o}$) gave upon treatment with n-butyllithium (-)-cis-2-p-methylphenyl-3-phenylcyclopropyl butyl ketone ($(\alpha)^{23}_{365} = -8.26^{o}$). Treatment of the (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid ($(\alpha)^{22}_{436} = -8.24^{o}$) with n-butyllithium gave (+)-cis-2-p-methylphenyl-3-phenylcyclopropyl butyl ketone ($(\alpha)^{22}_{365} = +6.45^{o}$). From this data, one can see the two acids

have different absolute configurations with V slightly more optically pure than VI.

When (+)-1-p-bromophenyl-3-p-methylphenylallene ($(\alpha)^{22}_{365}$ = +101.0°) was treated with n-butyllithium at 0°, the (+)-1-p-methylphenyl-3-phenylallene ($(\alpha)^{23}_{365}$ = +56.0°) was obtained. Again, relatively speaking, this means that the (+)-1-p-bromophenyl-3-p-methylphenylallene and the (-)-1-p-methylphenyl-3-phenylallene have different absolute configurations. Also, from the optical purities of the acids and the allene conversion data, one can say that the (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid (VI) gives an allene of higher optical purity than does the (-)-cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid (V). The interpretation of this data in terms of electronic effects and not steric effects will be taken up in the next chapter.

While working on the conversion of acid to ketone as shown in scheme IV, it was found that optically active acid VI of a positive rotation gave optically active ketone VII of a negative rotation. Optically active acid V of a negative rotation gave optically active ketone VII of a negative rotation.

It is also interesting to note that the GLC of ketone VII obtained from both acids V and VI gave only one peak, indicating only the cis isomer was present in each case.

This was verified by synthesizing the trans-2-p-methylphenyl-3-phenylcyclopropyl butyl ketone, using identical reaction and workup conditions as for the cis compounds, and comparing it to the corresponding cis ketone obtained from acids V and VI. No trans compound was detectable in the cis compounds nor any cis in the trans compound by GLC analysis. This indicates two things. One, that no trans ketone was present in the cis ketone prepared from cis acid V or VI. Two, the acids are stable to the reaction conditions.

Previous studies have indicated that 1,3-diphenylallene is optically stable in hexane, cyclohexene, and benzene when subjected to treatment with sodium methoxide in methanol (19). Also, the allene was shown to be optically stable to work up conditions such as silica gel column chromatography (hexane eluent). The allene also was optically stable in hexane solution (19). The (+)-1-p-bromophenyl-3-p-methylphenyl-allene, synthesized in this work, was found to be optically stable to hexane, silica gel chromatography, and sodium methoxide in methanol. In addition, the (-)-1-p-methylphenyl-3-phenylallene was found to be optically stable to n-butyl-lithium at 0^{o}. From this information, one can say that the activity of the allenes determined in this work is a true reflection of the activity of the allene as it was formed. It was also found that the rotations of 1-p-bromophenyl-3-p-methylphenylallene could be obtained within a range of

3.5° of each other in four different preparations of the allene from the corresponding carbamate.

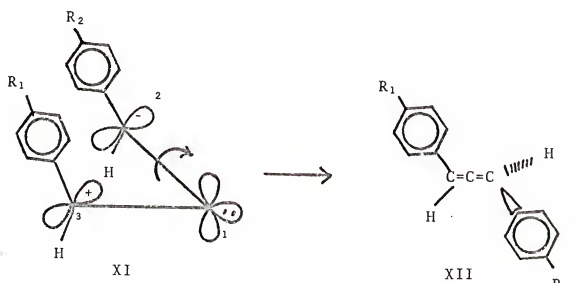
CHAPTER II

THE ORIGIN OF THE OPTICAL ACTIVITY

As already discussed in Chapter I, a sterically controlled ring opening for the cis-2,3-diarylcyclopropylidene (assuming no electronic effects and equal steric effects of the aryl groups) would lead to an inactive allene product. However, if the electronic effect of the aryl groups can be felt (assuming the aryl groups are equal sterically), the allene obtained should be optically active. The steric differences of the two aryl groups should be minimized in the ring opening process if the aryl groups differ only at the para positions. By having different substituents at the para position of each aromatic ring, the nature of the aromatic rings could be changed, which could in turn influence the transition state in the opening process in such a way as to lead to a preference of one enantiomer over another. To see how this might occur, one can visualize that the bond between C_2 and C_3 that must be broken in compound XI is influenced by the electronic effect of the substituent in the para position of the ring in such a manner as to partially polarize the bond, which in turn can influence the opening process. The extreme mechanism of the above would be to have the bond influenced in such a manner so that a

cation and anion would be formed. This is not to suggest that this is the transition state, but by looking at this extreme example of electronic influence one can see how the p-substituent groups may have an effect on the direction of electron flow, which in turn could be reflected in the optical activity of the product.

Consider then, for an example of this effect, the cis-2-p-methylphenyl-3-phenylcyclopropylidene XI where the bond between C_2 and C_3 has cleaved to give an ionic species that is preferred because of the electronic influences of the p-substituents on the aromatic rings, and where the carbene is in an sp^2 orbital. It can be seen that the empty



XI

XII

$R_1 = CH_3$, $R_2 = H$

Figure 5

cation orbital on C_3 is aligned with the filled orbital on C_1 in such a way that no rotation about the C_1 - C_3 bond is required to form allene. Rotation of the filled orbital on C_2 90^o in a clockwise manner about the C_1 - C_2 bond would align the empty orbital on C_1 with the filled orbital on C_2, and would form allene to give the enantiomer shown (XII). One can see that if a polarization of the bond between C_2 and C_3 is occurring, then a cis-diarylcyclopropylidene which is substituted in the para positions with an electron withdrawing substituent (R_2 = Br) in one para position, and an electron donating substituent (R_1 = CH_3) in the other, should have a greater influence on the polarization of the bond and should give an allene of higher optical purity than would the substituted cyclopropylidene XI.

However, it may be that the para substituents could have a steric influence on the ring opening process in the cis-substituted cyclopropylidenes. Since it is already known that the cyclopropylidenes XIII and XIV have different absolute configurations, let us examine the ring opening in terms of steric effects only and assume for the moment no electronic effects are felt.

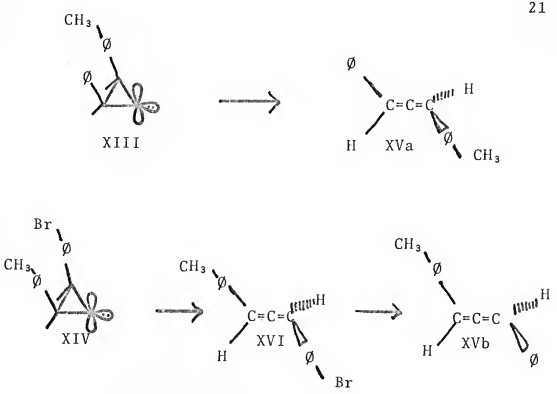


Figure 6

Since a methyl group is bigger sterically than a H atom, if steric influences are felt in the ring opening of the cyclopropylidene XIII, the rotation that probably would be preferred would be the rotation of the p-methylphenyl group outward resulting in the formation of allene enantiomer XVa. Since a bromine atom is also bigger than a hydrogen atom, the replacement of bromine for hydrogen in cyclopropylidene XIV would tend to decrease any steric effect that was occurring, and the result would be an allene of less optical purity than that produced from cyclopropylidene XIII. However, from the optical purity data it was seen that cyclopropylidene XIV produced allene of higher and not less optical purity than

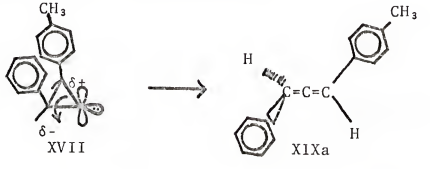
cyclopropylidene XIII. The presence of the bromine atom in cyclopropylidene XIV could also be sterically affecting the opening in such a manner that it would enhance the rotation of the p-bromophenyl group outward to give allene XVI. Conversion of allene XVI to allene XVb would give an allene that is the same enantiomer as XVa. But, again from experimental results, the allene XVa was found to have a different configuration rather than an identical configuration as the preceding steric requirement would indicate.

From these steric arguments then, the experimental data of optical purity and absolute configurations cannot be explained. Since the observed results cannot be explained in terms of steric effects, the ring opening must be an electronic effect. Indeed, consideration of electronic factors in the ring opening confirm this.

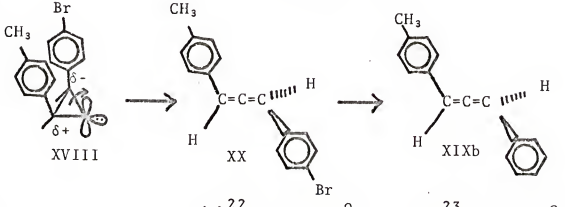
Again with the result in mind that the starting acids are of different absolute configurations, the cyclopropylidenes would have opposite configurations as shown below.

The ring opening of cyclopropylidene XVII to give allene XIXa is shown below. Cyclopropylidene XVIII opens to give allene XX which is converted to allene XIXb via n-butyllithium. By an electronically influenced ring opening mechanism, one can see that the substituted cyclopropylidenes XVII and XVIII, being of opposite configurations, must

give allenes XIXa and XIXb, respectively, which are of opposite configurations also. The experimental results bear this out, in that 1-p-methylphenyl-3-phenylallene is produced with opposite signs of rotation from XVII and XVIII, meaning the allenes are of different absolute configurations. Also, one would propose that allene XIXb should be produced with a higher optical purity than allene XIXa. Again, experimentally this is what is found.



$(\alpha)^{23}_{365} = -36.1^{o}$



$(\alpha)^{22}_{365} = +101.0^{o}$ $(\alpha)^{23}_{365} = +56.0^{o}$

↙ = Electronic argument

Figure 7

One does not know the absolute configuration of allene XIXa or XIXb, and so it could be possible that the allene represented as XIXa really has configuration XIXb. In other words, the sign of rotation of the allenes obtained experimentally just tells one the configurations of allene are different and not that configuration XIXa results from a substituted cyclopropylidene of configuration XVII, etc.

The rotations of the allene and ketone compounds of scheme IV were also taken at another wavelength besides the 365 mμ. wavelength shown. Acid V ($(\alpha)^{22}_{436} = -1.00^{o}$) gave ketone VII ($(\alpha)^{23}_{436} = -2.17^{o}$), and acid VI ($(\alpha)^{22}_{436} = -8.24^{o}$) gave ketone VII ($(\alpha)^{22}_{436} = +1.47^{o}$). Acid V gave allene VIII ($(\alpha)^{22}_{436} = -25.6^{o}$), and acid VI gave allene IX ($(\alpha)^{22}_{436} = +45.70^{o}$) which was converted to the allene X ($(\alpha)^{23}_{436} = +37.5^{o}$) via n-butyllithium. These results show (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid (VI) gives allene of highest optical purity and supports the above conclusions.

As already mentioned in Chapter I, all attempts to trap the cis-substituted cyclopropylidene intermediate by decomposition of the N-nitrosocarbamate with base in the presence of olefin failed. This points to quite an interesting phenomenon in the ring opening process of the cis-substituted cyclopropylidene to allene. The two aryl groups being cis

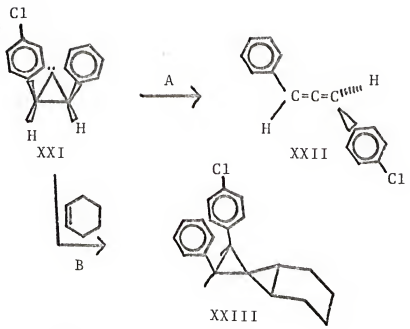


Figure 8

to each other in the cyclopropylidene XXI are sterically repelling each other. However, electronic effects are influencing one phenyl group to be rotating outward in preference over the other. So a steric assist to an electronically influenced ring opening is occurring. This steric assist causes the ring opening process (A) to be faster than the reaction of the carbene with the olefin (B), and, as a result, the carbene can't be trapped.

If the opening process for the cis-substituted cyclopropanes to allenes is concerted, Woodward-Hoffmann rules could be applied (25-26). Symmetry correlations can be applied to the opening of a substituted cyclopropylidene to a planar allene (planes x and y undergoing a total of 180^{o}

rotation). In this case the cyclopropylidene is considered similar in electronic structure to a cyclopropyl cation. This leads to the prediction that the carbene should open in a disrotatory mode. However, studies on the trans-2,3-diphenylcyclopropylidene have shown that the carbene opens in a conrotatory mode to give allene (11-12). This indicates that the cyclopropyl cation is a poor representation of the cyclopropylidene, and that the electron pair of the carbene is actually influencing the opening process. The non-bonded pair of the carbene could be thought of as participating in an elimination reaction, with C_2 or C_3 as the leaving group. The substituent effect could then be pictured as arising from its ability to stabilize the negative charge. In the extreme, this elimination process then is a breaking of the C_2 - C_3 bond, which would result in an intermediate anion which must undergo concerted rotation of the C_1 - C_3 bond 90^{o} to give the allene.

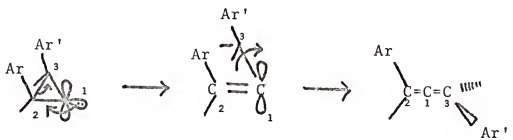


Figure 9

Before the acids and allenes were related as in scheme IV, other reagents were used in the sequence unsuccessfully. An attempt to convert 1-p-bromophenyl-3-p-methylphenylallene to 1-p-methylphenyl-3-phenylallene via a Grignard reaction failed. Also, initially it was thought the acids could be related by the reaction sequence given below.

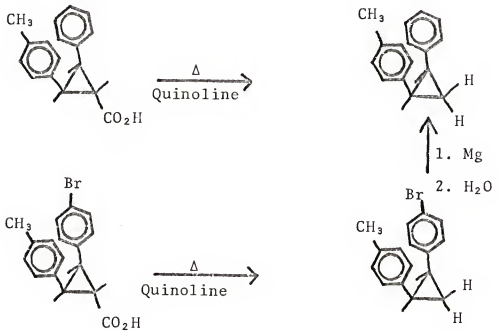


Figure 10

Decarboxylation of the cis-2-p-methylphenyl-3-phenyl-cyclopropanecarboxylic acid, in refluxing quinoline and copper chromite catalyst, gave a product whose n.m.r. spectrum indicated a cyclopropane compound, namely, 1-p-methylphenyl-2-phenylcyclopropane. However, when trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid was

decarboxylated under the same conditions (27), a product was obtained having an identical infrared, n.m.r., and mass spectrum as that of the cis decarboxylation product. Since the cis-1,2-diphenylcyclopropane is known to isomerize to the corresponding trans compound, but the trans compound does not isomerize to the cis compound (28), the substituted cyclopropane acid decarboxylations of above show that the cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid gave the trans-1-p-methylphenyl-2-phenylcyclopropane. The literature lists the absorption of the benzylic protons in the n.m.r. spectrum of cis and trans-1,2-diphenylcyclopropane as τ 7.55 and τ 7.87, respectively. The benzylic protons of the product obtained from both cis and trans decarboxylation reactions show an absorption at τ 7.83 in the n.m.r. spectrum. It is interesting to note that the acid recovered from the decarboxylation reaction of cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid is indeed the cis and not the trans acid. Therefore, the isomerization is taking place during or after the decarboxylation process. Because of this isomerization, the above correlation scheme was abandoned.

CHAPTER III

SUMMARY

In this work several cis-2,3-diarylcyclopropanecarboxylic acids were synthesized. The acids were prepared by addition of ethyl diazoacetate to substituted cis-stilbenes, which were prepared by conventional methods. The acids were resolved and converted to the ethyl N-nitroso-N-(cis-2,3-diarylcyclopropyl)carbamates via the acid chloride, acid azide, isocyanate, and carbamate. Decomposition of the N-nitrosocarbamates with base gave optically active 1,3-diaryl-allenes.

The activity of the allenes was shown to arise only from the cis-2,3-diarylcyclopropanecarboxylic acids, by preparation of the methyl ester and n-butyl ketone of each acid and GLC analysis. The methyl-trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylate and trans-2-p-methylphenyl-3-phenylcyclopropyl butyl ketone were synthesized for comparison with the corresponding cis compounds via GLC analysis.

A chemical correlation scheme relating the (-)-cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid to the (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic

acid was carried out. The (-)-1-*p*-methylphenyl-3-phenylallene was also related to the (+)-1-*p*-bromophenyl-3-*p*-methylphenylallene by chemical reactions. From this chemical correlation scheme, relatively speaking, it was found that the (-)-*cis*-2-*p*-bromophenyl-3-*p*-methylphenylcyclopropanecarboxylic acid gave allene of highest optical purity. The optical purity and relative absolute configuration data obtained from the correlation scheme tend to support an electronically influenced ring opening of the *cis*-substituted cyclopropylidene to a 1,3-diarylallene. The arguments involved in a steric versus an electronic ring opening are discussed.

CHAPTER IV

EXPERIMENTAL

General.--Melting points were determined on a Thomas-Hoover Capillary Melting Point Apparatus and are uncorrected. Boiling points reported are also uncorrected. Infrared spectra were obtained by use of a Beckmann Model IR10 infrared spectrophotometer. Ultraviolet spectra were recorded on a Cary 15 spectrophotometer. The Hitachi Perkin-Elmer RMU-6E mass spectrophotometer was used to record mass spectra. The ionizing voltage used was 70 e.V. unless otherwise indicated. Nuclear magnetic resonance spectra were determined with a Varian A-60 high-resolution spectrometer, using carbon tetrachloride as a solvent unless otherwise indicated. Chemical shifts are given as tau (τ) values from tetramethylsilane. Elemental analyses were performed by Galbraith Laboratories, Inc., Knoxville, Tennessee. Optical rotations were measured in one decimeter tubes with a Perkin-Elmer Model 141 high precision digital readout polarimeter. Concentrations are given as grams per ml. A Wilkens Aerograph Gas Chromatograph Model 600-D was used for gas-liquid chromatography. Analytical thin-layer chromatography was accomplished on 2" x 8" plates coated in this laboratory

with 0.25 mm. layers of Merck silica gel HF_{254} using ultraviolet detection unless otherwise specified.

Ethyl diazoacetate. The ester was prepared according to the procedure of Searle (29) from glycine ethyl ester hydrochloride. After drying the methylene chloride solution of the ester, the solvent was removed at room temperature by way of a rotary evaporator to give the ester as a yellow liquid. The ester was then further purified by distilling the compound under vacuum to give the yellow oil in 82 percent yield. This material was used directly in the preparation of the various cyclopropanes from the corresponding olefins.

α-Phenyl-p-chloro-trans-cinnamic acid. A modified method of Buckles and Bremer (15) was adapted to this synthesis by substituting p-chloro-benzaldehyde for benzaldehyde. In a 500 ml. round bottom flask was placed 113 g. (0.805 moles) of p-chloro-benzaldehyde, 110.0 g. (0.806 moles) of phenylacetic acid, 80 ml. of anhydrous triethylamine, and 160 ml. of acetic anhydride. The mixture was boiled gently under reflux for 9 hours. After the heating period was over, the mixture was allowed to come to room temperature and was then poured into 1000 ml. of 10 percent sulfuric acid solution which was magnetically stirred for two hours. The yellow solid was then separated by filtration and was washed

with pentane until the solid was white. The product was purified by recrystallization from chloroform. The overall yield of purified product, m.p. 201-203°, was 63 g. (34%). (Literature reports a m.p. of 200-201°) (16).

cis-4-Chlorostilbene. A modified procedure of Buckles and Wheeler (14) was used to synthesize this cis-stilbene. A 500 ml. three-necked flask was fitted with a reflux condenser and a thermometer, the bulb of which reached far enough into the flask to be covered by the liquid. A solution of 52.99 g. (0.205 moles) of α-phenyl-p-chloro-trans-cinnamic acid in 280 ml. (2.38 moles) of quinoline was added to the flask along with 4.0 g. of copper chromite. The reaction flask was heated by means of a mantle until the temperature of the reaction mixture reached 210-220°. The mixture was kept within this temperature for 1.25 hours. The solution was then cooled, 1000 ml. of ether was added to the reaction mixture, and the solution was filtered to remove particles of catalyst. The ether solution was then extracted with 1500 ml. of 10 percent hydrochloric acid in order to dissolve the quinoline. The ether solution was washed with 10 percent sodium hydroxide solution, to remove unreacted acid, and dried over anhydrous sodium sulfate. The dry solution was removed from the drying agent by filtration and the ether was removed by a rotary evaporator.

The residue was dissolved in hexane, cooled to 0°, and filtered to remove trans-stilbene. The hexane was removed by distillation and the cis-stilbene was distilled. The yield of cis-4-chlorostilbene was 32.7 g. (74%), b.p. 90-93°/0.5 mm. (Literature (16) reports b.p. 118-120°/1.5 mm. and 62-64% yield.) The infrared spectrum agreed with that reported for cis-4-chlorostilbene..

(±)-1-Carbethoxy-cis-2-p-chlorophenyl-3-phenylcyclopropane. A modified procedure of D'jakanov, et al. (30) was used for the addition of ethyl diazoacetate to cis-4-chlorostilbene. To 7.18 g. (0.0334 moles) of cis-4-chlorostilbene and 0.26 g. of anhydrous copper sulfate heated in an oil bath to 90°, with magnetic stirring, was added 6.87 g. (0.0491 moles) of ethyl diazoacetate dropwise during 2 hours. The reaction mixture was taken up in ether and extracted with water. The ether was removed by use of a rotary evaporator to give a light yellow liquid. The ester was not isolated but used directly in the preparation of (±)-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid.

(±)-cis-2-p-Chlorophenyl-3-phenylcyclopropanecarboxylic acid. To the ester from above was added 100 ml. of 5 percent methanolic potassium hydroxide and the solution was refluxed for 3 hours according to the literature procedure (30). Water was added to the reaction mixture and the water layer

was extracted with ether to recover unreacted cis-4-chlorostilbene. The dissolved ether was removed from the water layer by means of a rotary evaporator while heating to 50°. The water layer was then placed in a large beaker and 10 percent sulfuric acid was added until the solution was acidic to congo red. The acid was removed by filtration. Recrystallization from 95 percent ethanol-water gave 2.59 g. of acid as a white crystalline solid, m.p. 151-153° (28.4% yield based on cis-4-chlorostilbene). Infrared absorptions (KBr) were observed at: 3437, 3030, 2925, 2655, 2570, 1880, 1815, 1709, 1683, 1603, 1495, 1457, 1448, 1400, 1296, 1215, 1158, 1094, 1024, 1015, 940, 872, 820, 768, 751, 719, 699, 657, 590, 538, 526, 502, 432, 355, and 262 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ -0.90 (singlet, carboxyl hydrogen), 2.96 (multiplet, phenyls), 6.90 (doublet, hydrogens on cyclopropyl carbons adjacent to phenyls, J = 5 cps), and 7.52 (triplet, hydrogen on cyclopropyl carbon adjacent to carboxyl group, J = 5 cps) in the expected integral ratio of 1:9:2:1. The ultraviolet spectrum showed absorptions (95% ethanol solution) at: 221 (ε = 19,400) and 262 (ε = 1,790) mμ. as shoulders to an absorption at wavelength below 215 mμ. The mass spectrum showed m/e peaks at: 272 (molecular ion), 271, 237, 227, 192, and 77.

Anal. Calcd. for $C_{16}H_{13}ClO_2$: C, 70.40; H, 4.77; Cl, 13.02. Found: C, 70.36; H, 4.85; Cl, 12.80.

Resolution of cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid. Twenty-five grams (0.092 moles) of racemic acid was dissolved in 100 ml. of methylene chloride and the hot solution was added to 15.18 g. (0.092 moles) of ephedrine alkaloid dissolved in 25 ml. of hot methylene chloride. To this solution was added 110 ml. of hot hexane and the solution was left standing for 12 hours. The acid salt that formed was filtered and dried under vacuum to give 39.45 g. (98.2% yield) of white crystals m.p. 77-90°. A fractional recrystallization was then carried out on the salt by dissolving the salt in the minimum amount of methylene chloride, followed by addition of hexane until cloudiness began to appear in the solution. A small amount of methylene chloride was then added and the solution left to fractionally recrystallize. The progress of the resolution was followed by taking a small amount of the salt and treating it with 10 percent hydrochloric acid. The acid percipitate was filtered, washed with more 10 percent hydrochloric acid and also with water. The acid was dried and the rotation of the acid was taken.

After several fractional recrystallizations, a salt was obtained of m.p. 155-157°. Treatment of the salt with

10 percent hydrochloric acid in the manner described above gave 4.7 g. (18.8%) of (-)-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid m.p. 149-152°, $(\alpha)^{23}_{436}$ = -5.73° (c = 0.0122, 95% ethanol), $(\alpha)^{23}_{589}$ = -1.96° (c = 0.0122, 95% ethanol). The spectra of this compound are identical to those given for the racemic acid. This optically active acid was used to make the optically active carbamate.

Optically active cis-2-p-chlorophenyl-3-phenylcyclopropanecarbonyl chloride. The procedure of Walbrick, Wilson, and Jones (31) was used with modifications. To 4.66 g. (0.0171 moles) of the (-)-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid was added 25 ml. (41.5 g., 0.35 moles) of thionyl chloride at room temperature in a flask fitted with a magnetic stirrer and a drying tube. The mixture was stirred for 24 hours. At this time the solution was a light yellow color. The excess thionyl chloride was removed by use of a rotary evaporator with a bath temperature of 40-50°. Final traces of thionyl chloride were removed by pumping for one hour (0.25 mm.) at room temperature. A yellow oil was obtained and was used directly to prepare the corresponding acid azide.

Optically active cis-2-p-chlorophenyl-3-phenylcyclopropanecarbonyl azide. The crude acid chloride was converted

directly to the acid azide by the procedure of Wilson (32). The acid azide was not isolated but was converted directly to the isocyanate.

Optically active cis-2-p-chlorophenyl-3-phenylcyclopropyl isocyanate. The crude acid azide was converted directly to the isocyanate by the procedure of Wilson (32). The isocyanate was not isolated but was used directly to prepare the corresponding carbamate.

(-)-Ethyl N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)-carbamate. The carbamate was prepared by a modified procedure of Walbrick (19). To a benzene solution of optically active cis-2-p-chlorophenyl-3-phenylcyclopropyl isocyanate, prepared in the manner described above, was added 60 ml. of absolute ethanol, and the mixture was refluxed for 24 hours. The solvent was removed by use of a rotary evaporator with a bath temperature of 40-50°; and a light yellow solid remained. Recrystallization from 95 percent ethanol-water gave 4.70 g. (87.4% from the acid) of the carbamate in the form of a white solid, m.p. 140-141°. Infrared absorptions (KBr) were observed at: 3308, 3025, 2998, 2977, 1673, 1598, 1516, 1490, 1397, 1308, 1260, 1188, 1166, 1086, 1058, 1013, 939, 887, 860, 818, 785, 766, 745, 718, 700, 666, 608, 525, 500, and 431 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 3.01 (multiplet, phenyls), 4.87 (broad singlet,

hydrogen attached to nitrogen), 5.84 (quartet, methylene adjacent to oxygen, J = 7 cps), 6.7 (broad multiplet, hydrogen of cyclopropane carbon adjacent to nitrogen), 7.46 (doublet, hydrogens of cyclopropane carbons adjacent to phenyls, J = 5 cps), and 8.73 (triplet, methyl, J = 7 cps) in the expected integral ratio of 9:1:2:1:2:3. Ultraviolet absorptions (95% ethanol solution) were observed at: 223 (ε = 24,400) and 265 (ε = 2,140) mμ. as shoulders to an absorption below 210 mμ. The mass spectrum showed m/e peaks at: 315 (molecular ion), 314, 286, 242 (base peak), and 77. The carbamate had rotations of: $(\alpha)^{22}_{436} = -2.10^{o}$ (c = 0.0266, 95% ethanol), and $(\alpha)^{22}_{589} = -0.49^{o}$ (c = 0.0266, 95% ethanol).

Anal. Calcd. for $C_{18}H_{18}ClNO_2$: C, 68.62; H, 5.77; Cl, 11.23; N, 4.49. Found: C, 68.43; H, 5.90, Cl, 11.08; N, 4.37.

Optically active ethyl N-nitroso-N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate. The procedure of White and Aufdermarsh (33) was used with modifications. A mixture of 2.5 g. (0.00794 moles) of (-)-ethyl N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate, 4.15 g. (0.0507 moles) of anhydrous sodium sulfate, and 200 ml. of dry methylene chloride was cooled to -20^{o}, and a solution of 4.9 g. (0.0932 moles) of dinitrogen tetroxide in ether (prepared by bubbling the gas into a tared volumetric flask

about one-half full of ether at -50° and noting the increase in weight) was added until the blue-green color remained over a five-minute period. The excess dinitrogen tetroxide was removed *in vacuo*, and 100 ml. of cold ether was added. The reaction mixture was then washed once with cold sodium chloride solution, twice with cold saturated sodium bicarbonate solution, and once again with cold sodium chloride solution. The organic layer was dried over sodium sulfate and evaporated at room temperature by use of a rotary evaporator to a yellow oil, 2.6 g. (95%). The oil was shown to be homogeneous by thin-layer chromatography (elution with 50:50 hexane-ether), R_f = 0.340. The instability of this compound precluded analysis and because of its instability, the compound was used immediately to prepare the substituted allene. The method used to detect the nitroso compound was infrared analysis. The shift of the carbonyl in the N-nitrosocarbamate compound to 1752 $cm.^{-1}$ from the 1673 $cm.^{-1}$ absorption in the corresponding carbamate has been noted with other similar N-nitrosocarbamate compounds (19). The infrared spectrum of the N-nitrosocarbamate compound showed no absorption at 3308 $cm.^{-1}$, which is a major absorption in the carbamate spectrum. The infrared absorptions (liquid film) were observed at: 3028, 2980, 1752, 1602, 1517, 1496, 1447, 1400, 1377, 1342, 1274, 1190, 1094, 1019, 947, 909, 827, 769, 740, 713, 702, and 672 $cm.^{-1}$.

The N-nitrosocarbamate was used directly to prepare the allene.

(+)-1-p-Chlorophenyl-3-phenylallene. A modification of the procedure of Walbrick (19) was used. To a solution of 2.6 g. (0.0066 moles) of optically active ethyl N-nitroso-N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate (prepared from the corresponding carbamate, $(\alpha)_{436}^{22} = -2.10^{o}$ (c = 0.0266, 95% ethanol) in 100 ml. of hexane at room temperature, there was added 0.356 g. (0.066 moles) of sodium methoxide in methanol. Gas evolution began in approximately 20 seconds and continued for 45 minutes, at which time 149 ml. (100%) of gas had been evolved. The hexane was evaporated to a few ml. by way of a dry nitrogen stream and the reaction mixture was filtered through glass wool and column chromatographed over silica gel (purified hexane eluent). Fractions were monitored by use of thin-layer chromatography. Common fractions were combined. No other products were observed except the allene which had an R_f value of 0.40. GLC with a 0.125 inch by 5 foot column packed with 5 percent SE 30 on Chromosorb W with DMCS at 156^{o} and an inlet pressure of 20 p.s.i.g. gave only one peak with a retention time of 16.0 minutes. The allene fractions were evaporated by use of a dry nitrogen stream, combined, and made up to a 50 ml. volumetric solution. The

concentration of allene per ml. of this solution was determined by evaporation of a ml. of the solution and weighing the allene. A check on the concentration was also made by removal of the solvent (after 1 ml. was taken for rotational analysis) and weighing the remaining allene solid. The 1-*p*-chlorophenyl-3-phenylallene obtained in this manner had rotations of: $(\alpha)^{22}_{589} = +2.58^{o}$ (c = 0.0269, hexane), $(\alpha)^{22}_{436} = +5.95^{o}$ (c = 0.0269, hexane). The yield of allene was 1.35 g. (89.6%), m.p. 51-53°. Infrared absorptions (KBr) were observed at: 2979, 2802, 1929, 1879, 1589, 1566, 1483, 1426, 1382, 1159, 1092, 1013, 916, 881, 836, 823, 785, 738, 707, 691, 626, 636, 538, 525, 474, and 430 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 2.78 (multiplet, phenyls) and 3.48 (singlet, olefinic hydrogens) in the expected integral ratio of 9:2. The mass spectrum showed major absorptions at m/e: 226 (molecular ion), 225, 191 (base peak), 114, and 77. The ultraviolet spectrum (95% ethanol solution) showed absorptions at: 238 (ε = 21,800, shoulder), 258 (ε = 47,300), 288 (ε = 4,640, shoulder), and 295 (ε = 1,380, shoulder) mμ. The allene was quite unstable and decomposes to a yellow solid in a matter of hours if left exposed to the air. The instability of this compound precluded its analysis. The spectra of the allene obtained in this manner were identical to spectra of allene that was recrystallized from hexane.

α-Phenyl-p-methyl-trans-cinnamic acid. The α-phenyl-p-methyl-trans-cinnamic acid was prepared according to the procedure already given for the preparation of α-phenyl-p-chloro-trans-cinnamic acid, substituting p-tolualdehyde for p-chloro-benzaldehyde. Recrystallization from chloroform gave a white solid, m.p. 169-171° (49.8%) (literature reports m.p. 168°, and m.p. 173-174°, (50% yield)) (34-35). The ultraviolet spectrum also agreed with that given in the literature (34).

cis-4-Methylstilbene. α-Phenyl-p-methyl-trans-cinnamic acid was decarboxylated to give cis-4-methylstilbene according to the procedure already given for the decarboxylation of α-phenyl-p-chloro-trans-cinnamic acid. Distillation of the reaction product, after chromatography on neutral aluminia (hexane eluene), gave 13.90 g. (35% yield, b.p. 100-104°/0.425 mm. (literature reports (17) b.p. 100-112°/2 mm.)), of the cis-4-methylstilbene. The infrared and ultraviolet spectra matched those given in the literature (17).

(±)-1-Carbethoxy-cis-2-p-methylphenyl-3-phenylcyclopropane. This compound was prepared by the procedure already given for (±)-1-carbethoxy-2-p-chlorophenyl-3-phenylcyclopropane. The ester was not isolated, but was used directly to prepare the corresponding acid.

(±)-cis-2-p-Methylpheny1-3-phenylcyclopropanecarboxylic acid. This acid was prepared from the corresponding ester in the same manner as that already described for the (±)-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid. The racemic cis-2-p-methylpheny1-3-phenylcyclopropanecarboxylic acid was produced in 29.2 percent yield, m.p. 119-121°. The infrared spectrum (KBr) showed absorptions at: 3040, 2676, 2586, 1686, 1604, 1516, 1446, 1286, 1212, 1161, 1116, 1098, 1081, 1021, 950, 883, 813, 761, 724, 701, 688, 646, 628, 621, 541, 572, and 531 $cm.^{-1}$. The ultraviolet spectrum (95% ethanol) showed absorptions at: 226 (ε = 15,500) and 266 (ε = 708) mμ. as shoulders to an absorption below 220 mμ. The n.m.r. spectrum showed absorptions at: τ -2.2 (singlet, carbonyl hydrogen), 3.08 (multiplet, phenyls), 6.97 (doublet, two cyclopropane hydrogens adjacent to phenyls, J = 5 cps), 7.57 (triplet, cyclopropane hydrogen adjacent to carbonyl, J = 5 cps), and 7.80 (singlet, methyl on phenyl) in the expected integral ratio of 1:9:2:1:3. The mass spectrum showed major absorptions at m/e: 252 (molecular ion), 251, 239, 207, and 194 (base peak).

Anal. Calcd. for $C_{17}H_{16}O_2$: C, 80.99; H, 6.39. Found: C, 81.08; H, 6.43.

Resolution of cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid. This acid was resolved in the same manner as described for the cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid. To 37.35 g. (0.148 moles) of racemic cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid in 250 ml. of hot methylene chloride was added 24.4 g. (0.148 moles) of ephedrine in hot methylene chloride. Hot hexane was added (250 ml.) and the solution was left to cool. A salt was obtained, 56.17 g. (91.0%), m.p. 157-165°. After several fractional recrystallizations, a salt was obtained of m.p. 168-170°. The cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid obtained from the salt, 4.0 g. (10.7%) m.p. 114-116.5°, had a rotation of: $(\alpha)^{23}_{436} = -1.00^{\circ}$ (c = 0.031, 95% ethanol). The spectra of this active acid was identical to those of the racemic material. This acid was then used to make the corresponding carbamate.

(+)-Ethyl N-(cis-2-p-methylphenyl-3-phenylcyclopropyl)-carbamate. From 0.804 g. (0.00318 moles) of the optically active (-)-cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid, $(\alpha)^{23}_{436} = -1.00^{\circ}$ (c = 0.031, 95% ethanol), the corresponding carbamate was made according to the same procedure given for the (-)-ethyl N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)-carbamate. Again the intermediate acid chloride, acid azide, and isocyanate were not isolated. After the crude solid was

recrystallized from 95 percent ethanol-water, there was obtained 0.804 g. (85.7%) of the ethyl N-(cis-2-p-methylphenyl-3-phenylcyclopropyl)carbamate, m.p. 101-103°, $(\alpha)^{22}_{436}$ = +0.98° (c = 0.0203, 95% ethanol). The infrared spectrum (KBr) showed absorptions at: 3320, 3060, 2990, 2915, 1683, 1603, 1520, 1446, 1380, 1338, 1308, 1263, 1195, 1068, 943, 866, 810, 783, 756, 732, 702, 623, and 530 $cm.^{-1}$. The ultraviolet spectrum (95% ethanol) showed absorptions at: 226 (ε = 14,680) and 266 (ε = 1,320) mμ. as shoulders to an absorption below 220 mμ. The n.m.r. spectrum showed absorptions at: τ 2.98 (multiplet, phenyls), 4.84 (broad singlet of hydrogen attached to nitrogen), 5.82 (quartet, methylene hydrogens, J = 7 cps), 6.62 (multiplet, cyclopropane hydrogen adjacent to nitrogen), 7.45 (doublet, cyclopropane hydrogens adjacent to phenyls, J = 5 cps), 7.80 (singlet, methyl on phenyl), and 7.75 (triplet, methyl, J = 7 cps). The mass spectrum showed major absorptions at m/e: 295 (molecular ion), 294, 280, 265, 251, 207 (base peak), and 192.

Anal. Calcd. for $C_{19}H_{21}NO_2$: C, 77.41; H, 7.19; N, 4.75. Found: C, 77.26; H, 7.40; N, 4.85.

Ethyl N-nitroso-N-(cis-2-p-methylphenyl-3-phenylcyclopropyl)carbamate. The N-nitrosocarbamate was obtained from the corresponding carbamate by the same procedure already given for the preparation of the (-)-ethyl N-nitroso-N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate. From 0.10 g. (0.000339 moles) of (+)-ethyl N-(cis-2-p-methylphenyl-3-phenylcyclopropyl)carbamate, $(\alpha)^{22}_{436} = +0.98^{o}$ (c = 0.0203, 95% ethanol), there was obtained 0.108 g. (95%) of the corresponding N-nitrosocarbamate as a yellow oil. The oil was shown to be homogeneous by way of thin-layer chromatography, $R_f = 0.382$ in a 50:50 mixture of hexane and ether. Again, infrared analysis was used to detect the N-nitrosocarbamate compound. The infrared spectrum (oil film, IR 137) showed no absorption at 3320 $cm.^{-1}$ (N-H), and a shift of the 1683 $cm.^{-1}$ ($\rangle$C=O) absorption in the carbamate to 1759 $cm.^{-1}$ in the N-nitrosocarbamate. The infrared spectrum also showed absorptions at: 2980, 1640, 1512, 1370, 1332, 1265, 1179, 1090, 1012, 939, 898, 835, 813, 761, 737, and 692 $cm.^{-1}$. The instability of this compound precluded its analysis. The yellow oil was used directly to prepare the substituted allene.

(-)-1-p-Methylphenyl-3-phenylallene. This compound was prepared according to the procedure already given for the preparation of (+)-1-p-chlorophenyl-3-phenylallene. The

N-nitrosocarbamate, prepared from 0.10 g. (0.000399 moles) of (+)-ethyl N-(cis-2-p-methylphenyl-3-phenylcyclopropyl)-carbamate, $(\alpha)^{22}_{436} = +0.98^{o}$ (c = 0.0203, 95% ethanol), gave a hexane solution of 1-p-methylphenyl-3-phenylallene which had rotations of: $(\alpha)^{22}_{365} = -36.10^{o}$, $(\alpha)^{22}_{436} = -25.6^{o}$, and $(\alpha)^{22}_{589} = -4.44^{o}$ (c = 0.0018, hexane). Removal of solvent from the hexane-allene solution by way of a dry nitrogen stream and then pumping in vacuo gave 0.045 g. (64.2% based on the carbamate) of (-)-1-p-methylphenyl-3-phenylallane, m.p. = 51-52°, as a white solid. The rotation of the solid was $(\alpha)^{22}_{365} = -36.5^{o}$, $(\alpha)^{22}_{436} = -25.1^{o}$, and $(\alpha)^{22}_{589} = -4.10^{o}$ (c = 0.010, hexane). The infrared spectrum (KBr) showed absorptions at: 3025, 2920, 2800, 2722, 1933, 1513, 1493, 1454, 1322, 1259, 1194, 1160, 1107, 1080, 1024, 943, 917, 887, 830, 789, 757, 743, 709, 697, 650, 636, 587, 532, 482, and 455 $cm.^{-1}$. The ultraviolet spectrum (95% ethanol solution) showed absorptions at: 237 (shoulder, ε = 18,850), 257 (ε = 41,300), 288 (shoulder, ε = 3,630), and 293 (shoulder, ε = 1,295) mμ. The mass spectrum showed major absorptions at m/e: 206 (molecular ion), 205, 191, 190, 189, and 188. The n.m.r. spectrum showed absorptions at: τ 2.83 (multiplet, phenyls), 3.50 (singlet, vinyl hydrogens), and 7.67 (singlet, methyl) in the expected integral ratio of 9:2:3. Thin-layer chromatography with hexane gave one spot with a R_f value of 0.49. This allene was quite unstable

and decomposed to a yellow oil in a matter of hours if left exposed to the air at room temperature. The instability of this compound precluded its analysis. Spectra of recrystallized allene obtained were identical to that of the allene obtained by evaporation.

α-p-Bromophenyl-p-methyl-trans-cinnamic acid. This compound was prepared according to the procedure already given for the preparation of substituted cinnamic acids. From 100 g. (0.465 moles) of p-bromophenylacetic acid and 55.8 g. (0.465 moles) of p-tolualdehyde reacted according to the given procedure, there was obtained 59.6 g. (0.188 moles, 40.5% yield) of α-p-bromophenyl-p-methyl-trans-cinnamic acid, m.p. 216-219° after recrystallization from chloroform. The infrared spectrum (KBr) of the compound showed absorptions at: 3450, 3000, 2835, 1674, 1608, 1510, 1489, 1427, 1394, 1318, 1293, 1268, 1216, 1186, 1075, 1004, 861, 831, 822, 789, 756, 733, 621, 560, 540, and 500 $cm.^{-1}$. The mass spectrum showed major absorptions at m/e: 317 (molecular ion), 316, 302, 272, 193, 192, and 121. The n.m.r. spectrum (chloroform-d) showed absorptions at: τ 2.83 (multiplet, phenyls and vinyl hydrogen) and 7.72 (singlet, methyl) in the expected integral ratio of 9:3. Ultraviolet absorptions (95% ethanol solution) were observed at: 228 (shoulder, ε = 19,700) and 292 (ε = 17,140) mμ.

Anal. Calcd. for $C_{16}H_{13}BrO_2$: C, 60.55; H, 4.14; Br, 25.19. Found: C, 60.79; H, 4.21; Br, 25.21.

cis-4-Bromo-4'-methylstilbene. The cis-4-bromo-4'-methylstilbene was prepared by decarboxylation of α-p-bromophenyl-p-methyl-trans-cinnamic acid according to the procedure already given for the preparation of substituted cis-stilbene. The cis-4-bromo-4'-methylstilbene was obtained in 70.0 percent yield after chromatography on neutral Woelm alumina of activity 1. The cis-stilbene was distilled (b.p. 137-141°/0.275 mm.) before use to give a clear liquid that on standing forms crystals that have a m.p. of 29-30°. Thin-layer chromatography (hexane eluent) showed only one spot with a R_f value of 0.15. GLC of the stilbene with a 0.125 inch by 5 foot column packed with 5 percent SE 30 on Chromosorb W with DMCS at 173° and an inlet pressure of 22 p.s.i.g. on the 600-D instrument gave only one peak at a retention time of 7.3 minutes. The infrared spectrum (KBr) showed absorptions at: 3017, 2923, 2863, 1905, 1709, 1588, 1513, 1485, 1418, 1393, 1223, 1186, 1151, 1107, 1074, 1013, 950, 882, 826, 800, 752, 704, 558, 481, and 310 $cm.^{-1}$. The ultraviolet spectrum showed absorptions (95% ethanol solution) at: 226 (ε=26,100, shoulder), 231 (ε = 21,900, shoulder), and 286 (ε = 12,600) mμ. The n.m.r. spectrum absorptions were observed at:

τ 2.80 (A_2B_2 pattern with shoulders, phenyls), 3.32 and 3.58 (overlapping doublets, two vinyl protons, J = 12 cps), and 7.7 (singlet, methyl) in the expected integral ratio of 8:2:3. The mass spectrum showed m/e peaks at: 273 (molecular ion), 258, 194, 193, and 178 (base peak).

Anal. Calcd. for $C_{15}H_{13}Br$: C, 66.10; H, 4.82; Br, 29.20. Found: C, 66.21; H, 4.85; Br, 29.08.

cis-2-p-Bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid. This acid was prepared according to procedure already given for the preparation of cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid using cis-4-bromo-4'-methylstilbene instead of cis-4-chlorostilbene. The intermediate ester was not isolated but was used directly to make the acid. The cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid was obtained in 30.6 percent yield as brown crystals. The acid was not purified further but was used directly to make the ephedrine salt for resolution of the acid by fractional recrystallization.

Resolution of the cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid. This acid was resolved by the method already given for other substituted cyclopropane acids. To 21.1 g. (0.0638 moles) of racemic cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid in 25 ml. of hot methylene chloride was added 10.6 g. (0.0638 moles)

of ephedrine in 25 ml. of hot methylene chloride. The mixture was left to cool and 26.35 g. (83.0%) of salt was obtained, m.p. 185-198°. After several fractional recrystallizations of the salt from methylene chloride, a salt was obtained that had a m.p. of 198-201°. The 6.50 g. (30.8%) of cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid that was obtained from this salt had a m.p. of 151-153°, and rotations of $(\alpha)^{22}_{365}$ = -15.1°, $(\alpha)^{22}_{436}$ = -8.24°, and $(\alpha)^{22}_{589}$ = -3.06° (c = 0.0085, 95% ethanol). Infrared spectrum (KBr) absorptions were observed at: 3000, 2770, 2580, 1900, 1709, 1689, 1518, 1493, 1454, 1393, 1301, 1286, 1215, 1161, 1094, 1084, 1012, 941, 881, 814, 729, 684, 641, 629, 562, 539, 518, 496, 472, and 442 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ -1.35 (broad singlet, carbonyl hydrogen), 3.15 (multiplet showing A_2B_2 pattern, phenyls), 7.02 (doublet, cyclopropane hydrogens adjacent to phenyls, J = 5 cps),and 7.68 (part of triplet overlapping with singlet, cyclopropane hydrogen adjacent to carboxyl group, and methyl) in the expected integral ratio of 1:8:2:4. Ultraviolet absorptions (95% ethanol solution) were observed at: 223 (ε = 21,500) and 266 (ε = 1,720) mμ. as shoulders to an absorption below 215 mμ. The mass spectrum showed m/e peaks at: 331 (molecular ion), 316, 286, 285, 284, 206 (base peak), 205, and 191.

Anal. Calcd. for $C_{17}H_{15}BrO_2$: C, 61.70; H, 4.58; Br, 24.10. Found: C, 61.91; H, 4.64; Br, 23.85.

(-)-Ethyl N-(cis-2-p-bromophenyl-3-p-methylphenylcyclopropyl)carbamate. From 3.0 g. (0.00906 moles) of (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid, the (-)-ethyl N-(cis-2-p-bromophenyl-3-p-methylphenylcyclopropyl)carbamate was obtained according to the procedure already given for the preparation of other carbamates via the acid chloride, acid azide, and isocyanate where these intermediate compounds were not isolated. The yield of the (-)-ethyl N-(cis-2-p-bromophenyl-3-p-methylphenylcyclopropyl)-carbamate was 2.6 g. (76.9%), m.p. 155-157°. The carbamate had rotations of $(\alpha)^{22}_{365}$ = -8.85° and $(\alpha)^{22}_{589}$ = -1.15° (c = 0.0113, 95% ethanol). Infrared absorptions (KBr) were observed at: 3250, 3064, 3024, 2985, 2922, 1713, 1690, 1553, 1520, 1493, 1400, 1369, 1313, 1280, 1234, 1197, 1166, 1172, 1015, 978, 948, 870, 812, 793, 745, 690, 600, 558, 547, 517, 504, 480, and 453 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 3.10 (an A_2B_2 multiplet, phenyls), 4.87 (broad singlet, hydrogen attached to nitrogen), 5.85 (quartet, methylene group, J = 7 cps), 6.73 (multiplet, cyclopropane hydrogen adjacent to nitrogen), 7.50 (doublet, cyclopropane hydrogens adjacent to phenyls, J = 5 cps), 7.78 (singlet, methyl on phenyl), and 8.74 (triplet, alkyl methyl group,

J = 7 cps) in the expected integral ratio of 8:1:2:1:2:3:3. Ultraviolet absorptions (95% ethanol solution) were observed at: 224 (ε = 18,500) and 274 (ε = 880) mμ. as shoulders to an absorption below 215 mμ. The mass spectrum showed major absorptions at m/e: 374 (molecular ion), 359, 345, 330, 287 (base peak), 286, 285, 206, and 179.

Anal. Calcd. for $C_{19}H_{20}BrNO_2$: C, 61.10; H, 5.40; N, 3.75; Br, 21.30. Found: C, 61.05; H, 5.47; N, 3.89; Br, 21.10.

Optically active ethyl N-nitroso-N-(cis-2-p-bromophenyl-3-p-methylphenylcyclopropyl)carbamate. This N-nitrosocarbamate was prepared according to the procedure already given for the preparation of other N-nitrosocarbamates. From 0.50 g. (0.00134 moles) of (-)-ethyl N-(cis-2-p-bromophenyl-3-p-methylphenylcyclopropyl)carbamate, $(\alpha)^{22}_{365}$ = -8.85 (c = 0.0113, 95% ethanol), 0.515 g. (97.2%) of the corresponding N-nitrosocarbamate was obtained as a yellow-green oil. The infrared spectrum (film, IR 137) of the oil gave absorptions at: 2970, 1756, 1723, 1640, 1513, 1490, 1370, 1342, 1277, 1270, 1182, 1152, 1115, 1072, 1010, 944, 910, 845, 809, 766, 735, and 707 $cm.^{-1}$ (there was no N-H (3250 $cm.^{-1}$) absorption). The oil was quite unstable and its instability precluded its analysis. Infrared analysis was used to detect the N-nitrosocarbamate, and the yellow-

green oil was used directly to prepare the substituted allene.

(+)-1-p-Bromophenyl-3-p-methylphenylallene. This allene was obtained by treatment of the optically active ethyl N-nitroso-N-(cis-2-p-bromophenyl-3-p-methylphenylcyclopropyl)carbamate with base in the manner already described for the preparation of other substituted allenes. The 1-p-bromophenyl-3-p-methylphenylallene obtained in the above manner was made up to a 50 ml. volumetric solution of allene in hexane. The rotations of 1-p-bromophenyl-3-p-methylphenylallene obtained in this manner were $(\alpha)^{22}_{365}$ = +101.2°, $(\alpha)^{22}_{436}$ = +45.7°, and $(\alpha)^{22}_{589}$ = +19.45° (c = 0.00411, hexane). Again the concentration was determined by evaporating 1 ml. samples of the volumetric solution and determining the weight of allene remaining. A check on the concentration was also obtained by removal of hexane from the volumetric solution of hexane and allene by use of a dry nitrogen stream and pumping in vacuo. Upon removal of the solvent, the (+)-1-p-bromophenyl-3-p-methylphenylallene was obtained as white crystals, m.p. 95-96°. The yield of allene in the original volumetric solution was 0.205 g. (53.7% based on the carbamate). The solid had rotations of $(\alpha)^{22}_{365}$ = +102.8°, $(\alpha)^{22}_{436}$ = +46.10°, and $(\alpha)^{22}_{589}$ = +19.10° (c = 0.019, hexane). The infrared spectrum (KBr) showed absorptions at:

3025, 2925, 1935, 1903, 1709, 1646, 1601, 1583, 1555, 1510, 1486, 1448, 1406, 1358, 1221, 1183, 1163, 1111, 1075, 1039, 1013, 963, 948, 872, 831, 819, 758, 736, 718, 688, 600, 570, 531, 508, and 300 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 2.78 (multiplet with A_2B_2 pattern, phenyls), 3.53 (singlet, olefinic hydrogens), and 7.67 (singlet, methyl) in the expected integral ratio of 8:2:3. Ultraviolet absorptions (95% ethanol) were observed at: 243 (shoulder, ε = 23,900), 264 (ε = 49,500), 287 (shoulder, ε = 10,350), and 295 (shoulder, ε = 6,060) mμ. The mass spectrum showed major absorptions at m/e: 285 (molecular ion), 284, 270, 205, 204 (base peak), and 189. Thin-layer chromatography with hexane showed one spot with a R_f value of 0.42. The (+)-1-p-bromophenyl-3-p-methylphenylallene on exposure to air would decompose to a yellow solid. The instability of this compound precluded its analysis. Again, the allene obtained in the above manner had identical spectra to that of the allene that was recrystallized from hexane.

trans-4-Methylstilbene. This compound was prepared according to the procedure of Wells (20) using 38.9 g. (0.316 moles) of p-tolualdehyde in place of p-chlorobenzaldehyde and reacting this compound with the Grignard reagent of benzyl chloride. After workup and recrystallization from hexane, crystals were obtained, 16.56 g. (27.0%) which had a

m.p. of 114-115°. (Literature (34) reports m.p. of 118-119° with recrystallization from 95% ethanol.) The spectra and analysis of this compound agreed with those given in the literature (34).

trans-2-p-Methylphenyl-3-phenylcyclopropanecarboxylic acid. This acid was prepared from trans-4-methylstilbene, according to the same procedure already given for the preparation of the cis-substituted cyclopropanecarboxylic acids, without isolation of the intermediate ester. From 11.9 g. (0.0613 moles) of trans-4-methylstilbene there was obtained, after recrystallization from 95 percent ethanol-water, 4.1 g. (27.3%, m.p. 146-148°) of trans-2-p-methylphenyl-3-phenyl-cyclopropanecarboxylic acid. Infrared absorptions (KBr) were observed at: 3458, 3028, 2928, 2750, 2642, 1681, 1605, 1518, 1498, 1463, 1448, 1353, 1326, 1268, 1238, 1155, 1110, 1096, 1020, 953, 916, 882, 810, 768, 699, 682, 593, 542, and 499 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 0.40 (broad singlet, carboxyl hydrogen), 2.82 (multiplet, phenyls), 6.98 (multiplet, cyclopropane hydrogens adjacent to phenyls), and 7.67 (multiplet, cyclopropane hydrogen adjacent to carboxyl group and methyl) in the expected integral ratio of 1:9:2:4. The ultraviolet spectrum (95% ethanol) showed absorptions at: 223 (ε = 18,650) and 265 (ε = 388) mμ. as shoulders to an absorption below 215 mμ.

The mass spectrum showed major absorptions at m/e: 252 (molecular ion), 251, 207 (base peak), 206, 192, 191, and 115.

Anal. Calcd. for $C_{17}H_{16}O_2$: C, 80.99; H, 6.39. Found: C, 81.14; H, 6.19.

Diazomethane. Diazomethane was prepared according to the procedure of Arndt (36) from nitrosomethylurea. However, the ether solution of diazomethane was not distilled off, but was decanted off the basic water layer to give an ether solution of diazomethane that was used directly for esterification reactions.

(-)-Methyl-cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylate. To an ether solution of 0.3 g. (0.00119 moles) of cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid, $(\alpha)_{436}^{23}$ = -1.0° (c = 0.031, 95% ethanol), cooled to 0°, there was added an ether solution of diazomethane until the faint yellow color of the diazomethane remained. The excess diazomethane was then destroyed by adding a few drops of acetic acid. The ether solution was washed with sodium bicarbonate solution and water. The ether layer was dried over anhydrous sodium sulfate. The ether solution was then removed by use of a rotary evaporator, and the remaining oil was chromatographed (50:50 mixture of pentane-ether eluent) over basic aluminia of activity III to give a clear, color-

less oil (0.294 g., 93%). The ester had rotations of $(\alpha)^{23}_{436} = -0.78^{o}$ (c = 0.0128, pentane), and $(\alpha)^{23}_{365} = -1.80^{o}$. Thin-layer chromatography showed one spot (50:50 pentane-ether eluent) with a R_f value of 0.32. GLC using a 0.125 inch by 5 foot column packed with 5 percent SE 30 on Chromosorb W with DMCS at 179^{o} and an inlet pressure of 25 p.s.i.g. showed only one peak with a retention time of 8.0 minutes for the compound before and after the basic aluminia column. Infrared spectrum absorptions (liquid film) were observed at: 3030, 2955, 2862, 1730, 1605, 1583, 1520, 1500, 1443, 1307, 1290, 1255, 1200, 1175, 1120, 1083, 1057, 1025, 1010, 920, 900, 885, 843, 815, 763, 728, 702, 648, 630, 540, 520, 472, and 290 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 3.13 (multiplet, phenyls), 6.33 (singlet, methoxymethyl), 7.10 (doublet, two cyclopropane hydrogens adjacent to phenyls, J = 5 cps), and 7.73 (overlapping triplet and singlet, methyl on phenyl and cyclopropane hydrogen adjacent to ester group, for the triplet, J = 5 cps) in the expected integral ratio of 9:3:2:4. Ultraviolet absorptions (95% ethanol solution) were observed at: 219 (ε = 20,100) and 266 (ε = 446) mμ. as shoulders to an absorption below 215 mμ. The mass spectrum showed major absorptions at m/e: 266 (molecular ion), 251, 207 (base peak), 206, 119, and 115.

Anal. Calcd. for $C_{18}H_{18}O_2$: C, 81.20; H, 6.83. Found: C, 81.13; H, 7.00.

Methyl-trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylate. This compound was prepared according to the already given procedure used to prepare the corresponding cis compound. From 0.30 g. (0.00119 moles) of trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid, there was obtained 0.30 g. (95%) of solid crystals, after column chromatography over basic aluminia (50:50 pentane-ether eluent) of activity III, which had a m.p. of 42-44°. Thin-layer chromatography (50:50 pentane-ether eluent) showed only one spot with a R_f = 0.30. GLC using the same conditions as with the corresponding cis compound showed only one peak with retention time of 10 minutes. Infrared spectrum (liquid film) absorptions were observed at: 3030, 2955, 2860, 1730, 1606, 1582, 1520, 1500, 1442, 1360, 1270, 1195, 1170, 1082, 1070, 1032, 985, 910, 886, 842, 815, 776, 758, 740, 700, 595, 530, and 219 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 2.83 (multiplet, phenyls), 6.53 (singlet, methoxy methyl), 7.07 (broad multiplet, two cyclopropane hydrogens adjacent to phenyl), and 7.73 (multiplet, methyl on aromatic and cyclopropane hydrogen adjacent to ester function) in the expected integral ratio of 9:3:2:4. Ultraviolet absorptions (95% ethanol solution) were observed

at: 222 (ε = 23,200), 265 (ε = 866), and 277 (ε 563) mμ. as shoulders to an absorption below 215 mμ. The mass spectrum showed major absorptions at m/e: 266 (molecular ion), 251, 231, 207 (base peak), 119, and 115.

Anal. Calcd. for $C_{18}H_{18}O_2$: C, 81.20; H, 6.83. Found: C, 80.98; H, 7.07.

(-)-Methyl-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylate. This compound was prepared from 0.30 g. (0.0011 moles) of (-)-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid, $(\alpha)^{23}_{436} = -5.73^{o}$ (c = 0.0122, 95% ethanol), according to the procedure already given for the preparation of (-)-methyl-cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylate. The (-)-methyl-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylate was obtained in 89.5 percent (0.281 g.) yield as a clear, colorless oil, after chromatography over basic aluminia of activity III (50:50 pentane-ether eluent), with rotations of $(\alpha)^{23}_{365} = -8.15^{o}$ and $(\alpha)^{23}_{436} = -4.46^{o}$ (c = 0.0092, pentane). Thin-layer chromatography showed only one spot at $R_f = 0.78$ using ether as a solvent. GLC of the oil using the same column as described for the other methyl esters, with an inlet pressure of 20 p.s.i.g. operating at 181^{o}, gives only one peak at a retention time of 12.3 minutes. The infrared spectrum (liquid film) of this compound showed absorptions

at: 3030, 2955, 2850, 1727, 1605, 1496, 1444, 1401, 1300, 1280, 1198, 1175, 1096, 1058, 1018, 918, 880, 822, 771, 755, 722, 701, 592, 531, 510, and 290 cm.$^{-1}$. The n.m.r. spectrum showed absorptions at: τ 3.15 (multiplet, phenyls), 6.33 (singlet, methoxy methyl), 7.08 (doublet, cyclopropane hydrogens adjacent to phenyls, J = 5 cps), and 7.62 (triplet, cyclopropane hydrogen adjacent to ester function, J = 5 cps) in the expected integral ratio of 9:3:2:1. Ultraviolet absorptions (95% ethanol solution) were observed at: 222 (ε = 45,600) and 265 (ε = 2,060) mμ. as shoulders to an absorption below 215 mμ. The mass spectrum showed major absorptions at m/e: 286 (molecular ion), 227 (base peak), 192, 191, 149, and 115.

Anal. Calcd. for $C_{17}H_{15}ClO_2$: C, 71.19; H, 5.28; Cl, 12.36. Found: C, 71.12; H, 5.43; Cl, 12.11.

(-)-Methyl-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylate. This ester was prepared according to the procedure already given for similar compounds. From 0.51 g. (0.00154 moles) of the cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid, $(\alpha)^{22}_{436}$ = -8.24° (c = 0.085, 95% ethanol), 0.484 g. (91.3%) of the (-)-methyl-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylate was obtained as a clear, colorless oil, after purification by column chromatography over basic aluminia of activity III

(50:50 pentane-ether eluent), which had rotations of $(\alpha)^{23}_{365}$ = -12.7° and $(\alpha)^{23}_{436}$ = -7.10° (c = 0.0372, pentane). Thin-layer chromatography showed only one spot with a R_f value of 0.26 with a 50:50 pentane-ether solution as eluent. GLC using the same column as was used for the other similar methyl esters showed only one peak at 203° and 34 p.s.i.g. with a retention time of 7.6 minutes. Infrared absorptions (liquid film) were observed at: 3028, 2955, 2925, 1730, 1520, 1493, 1444, 1398, 1301, 1280, 1199, 1175, 1110, 1076, 1057, 1013, 918, 880, 815, 800, 750, 733, 640, 630, 565, 516, 472, and 287 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 3.20 (multiplet with A_2B_2 pattern, phenyls), 6.32 (singlet, methoxy methyl), 7.12 (doublet, two cyclopropane hydrogens adjacent to phenyls, J = 5 cps), and 7.72 (overlapping triplet and singlet, cyclopropane hydrogen adjacent to ester function and methyl on aromatic ring, for triplet, J = 5 cps) in the expected integral ratio of 8:3:2:4. Ultraviolet absorptions (95% ethanol solution) were observed at: 224 (ε = 23,400) and 266 (ε = 1,385) mμ. as shoulders to an absorption below 220 mμ. The mass spectrum showed major absorptions at m/e: 345 (molecular ion), 330, 297, 287, 207, 150, 119, 117, and 77.

Anal. Calcd. for $C_{18}H_{17}BrO_2$: C, 62.61; H, 4.97; Br, 23.14. Found: C, 62.92; H, 5.12; Br, 22.96.

Detection of methyl-trans-2-p-methylphenyl-3-phenyl-cyclopropanecarboxylate in the (-)-methyl-cis-2-p-methyl-phenyl-3-phenylcyclopropanecarboxylate compound by use of GLC. An analytical sample of 0.11729 g. (99.27 mole %) of the cis compound and 0.00086 g. (0.73 mole %) of the corresponding trans compound were dissolved in pentane and used for GLC analysis. The 600-D instrument with a 0.125 inch by 5 foot column packed with 5 percent SE 30 on Chromosorb W with DMCS at 175° and an inlet pressure of 28 p.s.i.g. was used for analysis. The cis and trans compounds alone gave single peaks at retention times of 8.3 and 10.0 minutes, respectively. The analytical mixture of cis and trans compounds gave a large peak and a very small peak at 8.3 and 10.0 minutes, respectively, at attenuation of 16. The mixture was analyzed again at attenuation 16 for the cis compound and was then switched to attenuation 1 for the trans compound, which gave a much larger peak than was observed for the trans at attenuation 16. The percent of the trans compound peak at attenuation 16 is 13.6 percent of the peak at attenuation 1. It follows then that at attenuation 1, one could detect 1/7.36 of the present trans concentration in the analytic mixture at attenuation of 1, or 0.10 mole percent trans. GLC of the cis compound only under the above conditions gives only one peak at 8.3 minutes retention time. The amount of trans compound that could be present

when the cis compound only is run under the above conditions must be lower than 0.10 mole percent. Anything over 0.10 mole percent should have been detected by the GLC analysis. When (-)-methyl-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylate and (-)-methyl-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylate were analyzed in the manner described above, these cis compounds only gave one peak corresponding to the cis isomer in each case and no other detectable peaks. For GLC conditions of these two cis compounds see the preparation experiment for each ester.

(-)cis-2-p-Methylphenyl-3-phenylcyclopropyl butyl ketone. This ketone was prepared from (-)cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid, $(\alpha)_{436}^{23} = -1.00^{o}$ (c = 0.031, 95% ethanol). A solution of 0.180 g. (0.000714 moles) of acid dissolved in 40 ml. of tetrahydrofuran was placed in a three-necked round bottom flask fitted with a reflux condenser, magnetic stirrer, and rubber septum. The flask was placed in a water bath at 22^{o}. A dry stream of nitrogen was passed over the tetrahydrofuran solution for 15 minutes. n-Butyllithium was then added by way of a syringe. After 2.67 ml. of a 1.6 M solution of n-butyllithium in hexane (six-fold molar excess) had been added, the solution turned to a dark red-black color. The reaction solution was kept at 22^{o} for 60 minutes. At this time, the reaction solution was cooled

to 20° and a saturated solution of sodium chloride in water was added to the flask. The dark color disappeared and a white precipitate formed. The reaction mixture was washed three times with a saturated solution of sodium chloride, three times with a 2N sodium hydroxide solution, and once again with sodium chloride solution. The tetrahydrofuran layer was dried over sodium sulfate and then the tetrahydrofuran solvent was removed by use of a rotary evaporator (water bath heated to 50°) to give a light yellow oil. The infrared spectrum of this crude oil showed absorptions at 3403 $cm.^{-1}$ (-OH) and 1691 $cm.^{-1}$ (>C=O). The oil was chromatographed over basic Woelm alumina of activity II. Pentane was used as the eluent for the first 300 ml. Ether was then used as the eluent for the next 450 ml. The ketone came off in the 350 ml. to 700 ml. fraction. Thin-layer chromatography showed only one spot (50:50 pentane-ether solvent) with R_f = 0.63. GLC analysis with a 0.125 inch by 5 foot column packed with 5 percent SE 30 on Chromosorb W with DMCS at 200° and an inlet pressure of 25 p.s.i.g. showed only one peak at a retention time of 9.3 minutes. Removal of the ether by a rotary evaporator gave 0.031 g. (14.9%) of a clear, colorless oil. The oil had rotations of $(\alpha)^{23}_{365}$ = -8.26° and $(\alpha)^{23}_{436}$ = -2.17° (c = 0.0046, pentane). The infrared spectrum (liquid film) showed absorptions at: 3031, 2960, 2930, 2875, 1694, 1602, 1580, 1517, 1498, 1450,

1408, 1365, 1322, 1304, 1277, 1210, 1192, 1163, 1127, 1063, 1022, 900, 870, 844, 810, 750, and 700 $cm.^{-1}$. The n.m.r. spectrum showed absorptions at: τ 3.12 (multiplet, phenyls), 7.42 (overlapping doublet (J = 5 cps), multiplet, and singlet; two cyclopropane hydrogens adjacent to phenyls, cyclopropane hydrogen adjacent to ketone function and methylene hydrogens adjacent to ketone, and methyl on aromatic ring, respectively), and 8.74 (broad multiplet, remaining methylene hydrogens and alkyl methyl) in the expected integral ratio of 9:7:7. The ultraviolet absorption (95% ethanol solution) was observed at 221 (ε = 14,600) mμ. as a shoulder to an absorption below 215 mμ. The mass spectrum showed major absorptions at m/e: 292 (molecular ion), 274, 235, 207 (base peak), 129, 115, and 91.

Anal. Calcd. for $C_{21}H_{24}O$: C, 86.24; H, 8.29. Found: C, 86.38; H, 8.17. This analysis done by Peninsular Chem. Research, Inc., Gainesville, Florida.

(+)-cis-2-p-Methylphenyl-3-phenylcyclopropyl butyl ketone. This compound was prepared according to the procedure already given for the preparation of the levorotatory isomer. From 0.085 g. (0.000258 moles) of (-)-cis-2-p-bromophenyl-3-p-methylphenylcyclopropanecarboxylic acid, there was obtained 14.4 mg. (19.2%) of the ketone as a clear, colorless oil. The infrared spectrum of the crude oil before basic

alumina column chromatography showed absorptions at 3403 $cm.^{-1}$ (-OH) and 1685 $cm.^{-1}$ ($\rangle C=O$) identical to the crude oil IR of the (-)-ketone. The rotation of some of the first cuts of ketone (after the basic aluminia column) was taken before all the cuts were combined. The first two cuts of ketone gave rotations of $(\alpha)^{22}_{365} = +6.28^{o}$ and $(\alpha)^{22}_{436} = +1.62^{o}$ (c = 0.0043, pentane). The combined cuts of the oil had rotations of $(\alpha)^{22}_{365} = +6.45^{o}$ and $(\alpha)^{22}_{436} = +1.47$ (c = 0.00683, pentane). GLC analysis showed only one peak at a retention time of 9.3 minutes using the same conditions as for the analysis of the (-)-ketone. The infrared, ultraviolet, n.m.r., and mass spectra of this (+)-ketone are identical to that of the (-)-ketone.

Anal. Calcd. for $C_{21}H_{24}O$: C, 86.24; H, 8.29. Found: C, 86.38; H, 8.17.

trans-2-p-Methylphenyl-3-phenylcyclopropyl butyl ketone. This compound was prepared according to the procedure already given for the preparation of the cis isomer. From 0.503 (0.00199 moles) of trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid, there was obtained 103 mg. (17.7%) of the ketone as a clear oil. The infrared spectrum (oil film) showed absorptions at: 3030, 2963, 2935, 2880, 1699, 1603, 1580, 1520, 1499, 1455, 1438, 1407, 1370, 1263, 1212, 1154, 1131, 1065, 1030, 1022, 985, 910, 808, 780, 742, and 700 $cm.^{-1}$.

The n.m.r. spectrum showed absorptions at: τ 2.97 (multiplet, phenyls), 7.50, and 9.00 (centers of two broad multiplet absorptions, three cyclopropane hydrogens, methyl on aromatic ring, methylene hydrogens adjacent to ketone function, remaining methylene hydrogens, and alkyl methyl) in the expected integral ratio of 9:15. The ultraviolet absorption (95% ethanol solution) was observed at 222 (ε = 19,750) mμ. as a shoulder to an absorption below 215 mμ. GLC analysis of the trans ketone using the same column as for the cis compound but at a temperature of 182° and an inlet pressure of 32 p.s.i.g. showed only one peak at 17.0 minutes. Analysis of the cis ketone under identical conditions gave only one peak for the (+) and (-) cis ketone at 13.3 minutes. No trans ketone could be detected in the (+) and (-) cis ketone. No cis ketone could be detected in the trans ketone. The mass spectrum showed major absorptions at m/e: 292 (molecular ion), 235, 208, 207 (base peak), 192, 129, 105, 91, and 77.

Anal. Calcd. for $C_{21}H_{24}O$: C, 86.24; H, 9.29. Found: C, 85.94; H, 8.52.

(+)-1-p-Methylphenyl-3-phenylallene from (+)-1-p-bromophenyl-3-p-methylphenylallene via n-butyllithium. Fifteen milliliters of anhydrous ether was used to dissolve 48.0 mg. (0.168 moles) of (+)-1-p-bromophenyl-3-p-methyl-

phenylallene, $(\alpha)^{23}_{365} = +101.0^{o}$, $(\alpha)^{23}_{436} = +45.7^{o}$ (c = 0.011, hexane), that was placed in a 50 ml. round bottom flask along with a magnetic stir bar. The solution was cooled to 0^{o} and 0.30 ml. (2.7 molar excess) of 1.6 M n-butyllithium was then added with stirring. The solution turned a light orange color. After 30 minutes, 10 ml. of water was added and the mixture turned a light yellow. The reaction mixture was extracted with water twice, and the ether layer dried over sodium sulfate. The ether solvent was removed by use of a dry nitrogen stream to give a light yellow oil which was chromatographed over silica gel (hexane eluent). Allene containing fractions were combined by way of TLC and made up to a 5 ml. volumetric solution in hexane. The rotations of one ml. of this solution were $(\alpha)^{23}_{365} = +56.0^{o}$ and $(\alpha)^{23}_{436} = +37.5^{o}$ (c = 0.004, hexane). Evaporation of the solvent by way of a dry nitrogen stream gave 20.0 mg. (57.8%) of (+)-1-p-methylphenyl-3-phenylallene as white crystals m.p. 50-52°. The n.m.r. spectrum showed absorptions at: τ 2.87 (multiplet, A_2B_2 pattern was not present, phenyls), 3.52 (singlet, olefinic protons), and 7.69 (singlet, methyl on aromatic ring) in the expected integral ratio of 9:2:3. The infrared spectrum of the product was identical to that of known (-)-1-p-methylphenyl-3-phenylallene and was not similar to (+)-1-p-bromophenyl-3-p-methylphenylallene. The mass spectrum showed an absorption at m/e 206 (molecular ion) and nothing at 285 in

accordance with (+)-1-p-methylphenyl-3-phenylallene. The ultraviolet spectrum (95% ethanol solution) showed absorptions at: 238 (shoulder, ε = 18,100), 258 (ε = 40,400), 288 (shoulder, ε = 2,780), and 292 (shoulder, ε = 1,350) mμ.

Stability of (-)-1-p-methylphenyl-3-phenylallene to n-butyllithium at 0°. To 0.10 g. of optically active (-)-1-p-methylphenyl-3-phenylallene, $(\alpha)^{23}_{365}$ = -8.35° (c = 0.0132, hexane), dissolved in ether, was added a 2 molar excess of n-butyllithium at 0° according to the procedure already given for the treatment of (+)-1-p-bromophenyl-3-p-methylphenylallene with n-butyllithium. A solid, 0.92 g. (92%), was obtained which had a m.p. of 50-51°. The rotation of the solid was $(\alpha)^{22}_{365}$ = -8.42° (c = 0.0265, hexane). Thin-layer chromatography (hexane eluent) showed only one spot. The n.m.r. spectrum and infrared spectrum were identical to that of (-)-1-p-methylphenyl-3-phenylallene.

Effect of Optically active (+)-1-p-bromophenyl-3-methylphenylallene on optically active (-)-1-p-methylphenyl-3-phenylallene. Having combined 14.1 mg. (94.77 mole %) of (-)-1-p-methylphenyl-3-phenylallene, $(\alpha)^{23}_{365}$ = -36.10° (c = 0.0118, hexane), and 1.1 mg. (5.33 mole %) of (+)-1-p-bromophenyl-3-p-methylphenylallene, $(\alpha)^{23}_{365}$ = +101.0° (c = 0.011, hexane), the rotation of the resulting mixture was $(\alpha)^{23}_{365}$ = -31.3° (c = 0.0152, hexane). The mass spectrum

showed absorptions at m/e 285 and 206 corresponding to the molecular weight of the allene compounds.

Decarboxylation of cis and trans-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid. The method of Jones and Wilson (27) for decarboxylation of trans-2,3-diphenylcyclopropanecarboxylic acid in refluxing quinoline, with copper chromite catalyst, was followed for the above two compounds. However, when the products of the trans and cis decarboxylation reactions were obtained, it was found that they had identical n.m.r. spectra and infrared spectra. The thin-layer chromatograph and mass spectrum of both reaction products were identical also. It seems then that the cis compound must be undergoing isomerization (to the trans product) after or during decarboxylation. The fact that isomerization occurs after or during decarboxylation is suggested by the fact that unreacted cis-2-p-methylphenyl-3-phenylcyclopropanecarboxylic acid has an identical infrared spectrum to that of the cis-substituted cyclopropane acid and different from that of the trans. The n.m.r. spectrum of the product of both reactions showed absorptions at: τ 3.00 (multiplet, phenyls), 7.83 (multiplet, cyclopropane hydrogens adjacent to the phenyls and methyl on aromatic ring), and 8.72 (multiplet, methylene cyclopropane hydrogens) in the expected integral ratio of 9:5:2. The mass spectrum of the product

of both reactions showed major absorptions at m/e: 208 (molecular ion), 193, 178, 142 (base peak), 141, and 115. Thin-layer chromatography (pentane eluent) showed for both reaction products a spot at R_f = 0.28 and a very small spot slightly ahead of the larger spot at R_f = 0.41. The infrared spectra (liquid film, IR 137) of both cis and trans reaction products were identical and showed absorptions at: 3020, 2935, 2872, 1940, 1902, 1795, 1687, 1648, 1605, 1497, 1439, 1372, 1301, 1266, 1208, 1180, 1152, 1112, 1097, 1070, 1030, 1018, 1000, 960, 943, 928, 905, 894, 846, 810, 761, 748, 738, 712, and 693 $cm.^{-1}$.

The reaction of ethyl N-nitroso-N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate with base in cyclohexene. A modified procedure of Walbrick (19) for the preparation of a spiro compound from ethyl N-nitroso-N-(trans-2,3-diphenylcyclopropyl)carbamate and cyclohexene in base was used. To a solution of 1.80 g. (0.00522 moles) of ethyl N-nitroso-N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate (prepared from the corresponding carbamate) in 100 ml. of cyclohexene at 22° was added 0.50 g. (0.00927 moles) of sodium methoxide in methanol. Gas evolution began after two minutes, and after 30 minutes a quantitative amount of gas had been evolved. At this time all but a few ml. of cyclohexene were removed in vacuo, and the reaction was chromatographed over

silica gel (hexane eluent). The fractions were analyzed for the spiro compound by GLC using a 0.125 inch by 5 foot column packed with 5 percent SE 30 on Chromosorb W with DMCS at 156° and an inlet pressure of 20 p.s.i.g. Under these conditions the allene had a retention time of 16.0 minutes and no other compounds were detected. Combination of all allene containing fractions and evaporation of the hexane gave 0.901 g. (77.2%) of 1-p-chlorophenyl-3-phenylallene, m.p. 53-55°. The n.m.r. spectrum and infrared spectrum of this allene were identical to that of known 1-p-chlorophenyl-3-phenylallene, and did not indicate any other compounds such as the spiro compound.

The reaction of ethyl N-nitroso-N-(cis-2-p-chlorophenyl-3-phenylcyclopropyl)carbamate with base in isobutylene. A modified procedure of that given for the reaction of this N-nitrosocarbamate with cyclohexene was used. To 0.788 g. (0.00250 moles) of the N-nitrosocarbamate (prepared from the corresponding carbamate) dissolved in 75 ml. of isobutylene, at -8.0° to -15.0°, was added 1.56 g. (0.0075 moles) of sodium laurylate. Gas evolution began immediately, and the reaction was continued for 30 minutes. At this time the reaction mixture was worked up as in the reaction with cyclohexene already given. GLC of the reaction mixture showed only allene present and no other compounds. Also, GLC of

fractions after silica gel chromatography showed only allene and no other compounds. The allene obtained, 0.462 g. (81.5%) had a m.p. of 53-55°. The n.m.r. spectrum and infrared spectrum of this allene were identical to that of 1-p-chlorophenyl-3-phenylallene.

Attempted conversion of (+)-1-p-bromophenyl-3-p-methylphenylallene to 1-p-methylphenyl-3-phenylallene by way of a Grignard reaction. A 25 ml. three-necked round bottom flask that was fitted with a condenser and drying tube, magnetic stir bar, rubber septum, and 0.0489 g. (3 mole excess) of magnesium was flame dried and placed in a water bath of 22°. After the apparatus was cooled to room temperature, a solution of 0.189 g. (0.000665 moles) of (+)-1-p-bromophenyl-3-p-methylphenylallene, $(\alpha)^{22}_{365}$ = +101.2° (c = 0.00411, hexane), in ether was added to the flask by way of a syringe. After 1 hour at room temperature the solution turned light yellow. Ten microliters of methyl iodide was added to the flask. After 3.5 hours the solution was yellow-orange in color and a white precipitate was present. The reaction mixture temperature was lowered to 0° and 5 ml. of water was added slowly to the flask. The reaction mixture was then acidified with 10 percent hydrochloric acid. The water layer was extracted with ether three times. The combined ether layers were dried over sodium sulfate. The ether was removed by

use of a dry nitrogen stream, and hexane was added to the yellowish-white solid. The hexane soluble material was column chromatographed over silica gel and the allene fractions combined by way of thin-layer chromatography. TLC showed no other products. The hexane solvent was removed by pumping in vacuo and the allene recovered showed a m.p. of 91-92°. The n.m.r. spectra indicated only 1-p-bromophenyl-3-p-methylphenylallene. The infrared spectrum indicated that some 1-p-methylphenyl-3-phenylallene might be present also. In an attempt to get more conversion of the (+)-1-p-bromophenyl-3-p-methylallene to 1-p-methylphenyl-3-phenylallene, reaction conditions were changed, such as longer time for reaction, heating to 35°, different solvent, and crystals of iodine added to the reaction. Also after one run, 1 ml. of a hexane solution of recovered 1-p-bromophenyl-3-p-methylphenylallene was placed in a polarimeter cell and the sample had no observed rotation. Since an excess of magnesium was used, the allene was probably racemizing in the work-up when 10 percent hydrochloric acid was used (37), and, indeed, in a separate experiment this was shown to be the case. However, with these facts in mind the Grignard reaction as a method of conversion of one allene to another was dropped.

α-p-Methylphenyl-p-bromophenyl-trans-cinnamic acid. This acid was prepared according to the procedure already given for the preparation of substituted cinnamic acids. p-Bromobenzaldehyde and p-tolyacetic acid were reacted under the already given conditions to give 164.0 g. (70.8%) of α-p-methylphenyl-p-bromophenylcinnamic acid, m.p. 189-191°. The n.m.r. spectrum showed absorptions at: τ 1.67 (broad singlet, carboxyl hydrogen), 2.67 (multiplet, phenyls and olefinic hydrogen), and 7.58 (singlet, methyl) in the expected integral ratio of 1:9:3. The mass spectrum showed major absorptions at m/e: 317 (molecular ion), 274, 192, and 178. The infrared spectrum (nujol, IR 137) showed an absorption at 1670 $cm.^{-1}$ (carbonyl). When this compound was treated with copper chromite in refluxing quinoline in an attempt to obtain the substituted stilbene, the reaction mixture showed no stilbene compounds by GLC analysis. The unreacted starting material was recovered and no other products were present.

Fractionation of optically active 1-p-chlorophenyl-3-phenylallene. When an optically active hexane solution of (-)-1-p-chlorophenyl-3-phenylallene, $(\alpha)^{22}_{589} = -13.5°$ (c = 0.0185, hexane) (prepared from (+)-cis-2-p-chlorophenyl-3-phenylcyclopropanecarboxylic acid, $(\alpha)^{22}_{589} = +15.3°$ (c = 0.012, 95% ethanol)) was cooled to -78°, the allene precipitate

obtained had no observed rotation, m.p. 55-56.5°. The filtrate rotation increased to $(\alpha)^{22}_{589}$ = -18.8° (c = 0.0133, hexane). Concentration of the filtrate and collection of another crop of crystals gave the allene, $(\alpha)^{22}_{589}$ = -3.01° (c = 0.0103, hexane), m.p. 55-57°, and the solution had a rotation of $(\alpha)^{22}_{589}$ = -36.6° (c = 0.0069, hexane). Repeating this process twice more gave an allene precipitate of rotation $(\alpha)^{22}_{589}$ = -35.9° (c = 0.0046, hexane), m.p. 53-54.5°, and a solution of allene in hexane that had a rotation of $(\alpha)^{22}_{589}$ = -79.7° (c = 0.0340, hexane).

Stability of optically active 1-p-bromophenyl-3-p-methylphenylallene to sodium methoxide, and silica gel. This allene was prepared according to the procedure already given for the preparation of allenes from the corresponding N-nitrosocarbamates. The carbamate in this case had a rotation of $(\alpha)^{22}_{365}$ = -8.85° (c = 0.0113, 95% ethanol). In four different runs to prepare the allene, different amounts of N-nitrosocarbamate were used, different amounts of silica gel were used for the column chromatography of the allene in hexane solution, different amounts of sodium methoxide were used, and the time of reaction of the N-nitrosocarbamate with sodium methoxide was varied. From four such reactions, allene was obtained with rotations of $(\alpha)^{22}_{365}$ = 101.2°, 104.0°, 100.5°, and 101.0°; thus $(\alpha)^{22}_{365}$ = 102.3° ± 1.8°.

Runs	Time N-nitroso-carbamate was reacted with base	Moles of base used per mole N-nitroso	Amt. of silica gel used	Rotation of allene
1	30 min.	5	10 g.	101.2^{o}
2	30 min.	5	50 g.	104.0^{o}
3	2 hrs.	1	10 g.	100.5^{o}
4	30 min.	1	10 g.	101.0^{o}

From this data it is quite evident that the allene was stable to excess sodium methoxide and does not racemize on silica gel.

Optical stability of 1-p-methylphenyl-3-phenylallene to silica gel. Optically active allene $(\alpha)^{22}_{365} = -8.35^{o}$ (c = 0.0132, hexane) was chromatographed over 20.0 g of silica gel (hexane eluent). The resulting hexane solution of allene had a rotation of $(\alpha)^{22}_{365} = -8.70^{o}$ (c = 0.0085, hexane).

Optical stability of (+)-1-p-bromophenyl-3-p-methylphenylallene in hexane. A solution of the allene $(\alpha)^{22}_{365} = +104.0^{o}$ (c = 0.00404, hexane), which was allowed to stand in a polarimeter cell in hexane solvent under nitrogen, showed no change in rotation after 3 days.

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This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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